CHALMERS
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Coastal Shipping - a Competitive Alternative for Container Transportation?

- A Theoretical Case Study of Container Shipping Between Uddevalla and Gothenburg

Master's Thesis in the Master's Programme Supply Chain Management

ISABELLE CEDULF
MARTINA ANDREASSON

Supervisor: Magnus Blinge

Department of Technology Management and Economics
Division of Service Management and Logistics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017
Report No. E2017:044

MASTER'S THESIS E2017:044

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Department of Technology Management and Economics
Division of Service Management and Logistics
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone: + 46 (0)31-772 1000

Chalmers Reproservice
Gothenburg, Sweden 2017

Acknowledgements

We, the authors of this thesis, would like to express our gratitude towards all persons who have contributed with their time and knowledge during this study.

First of all, we would like to thank Christian Finnsgård at SSPA who gave us the opportunity to write this thesis. Christian has been a great support and has provided us with helpful insights about the project. We would also like to thank Vendela Santén and Martin Svanberg at SSPA for their valuable feedback and engagement.

Furthermore, we are grateful for the guidance provided by our supervisor Magnus Blinge, senior lecturer at the Division of Service Management and Logistics at Chalmers. Magnus has kindly shared his knowledge and encouraged us with uplifting comments throughout the writing process.

Finally, we would like to thank all interviewees who have participated in our study and provided us with valuable information. Without their input, this thesis would not have been possible. A special thanks to Patric Grund who represents SMTF in the NÖKS II project. His knowledge has been of great importance when developing the economic calculation model.

Isabelle Cedulf and Martina Andreasson

Gothenburg, May 2017

Abstract

There are no containers transported with maritime transportation within Sweden today. Despite unutilized capacity at sea along the Swedish coastline, all domestic container transportation to and from Swedish ports are made by road or rail transport. The inland transport infrastructure is heavily utilized and unless finding new transport solutions, the increasing volumes of transported cargo will require investments in new infrastructure. The use of coastal shipping could contribute to reduced utilization of roads and railways. It is therefore of interest to investigate the possibilities of using coastal shipping as an alternative to land-based container transport in Sweden. One route where coastal shipping could be a possible alternative is between Port of Uddevalla and Port of Gothenburg. The purpose of this study is therefore to evaluate if and how coastal shipping of containers between Port of Uddevalla and Port of Gothenburg can be a competitive alternative to rail and road transportation.

The case studied in this report is a theoretical case since no containers are transported by coastal shipping on the route today. To evaluate the competitiveness of this theoretical case, findings from previous research regarding coastal shipping have been reviewed and interviews with actors involved in the case have been conducted. The economic, logistic and environmental performance of the theoretical case has been calculated and qualitatively analysed. The results show that there are certain requirements regarding total cost, reliability, frequency, volume flexibility and environmental impact that must be met in order to establish a competitive coastal shipping solution between Port of Uddevalla and Port of Gothenburg. With the prerequisites of today, the requirements regarding total cost and environmental impact cannot be met. To make the coastal shipping solution competitive, costs of loading and unloading containers in the ports must be reduced and fuel-efficient vessels with gas cleaning systems must be used.

The study resulted in three theoretical frameworks regarding the economic, logistic and environmental performance of coastal shipping. These frameworks are possible to apply on other cases as well and they are therefore part of this study’s contribution to theory. Furthermore, a list of requirements for a competitive coastal shipping solution was developed, as well as an economic performance calculation model. These theoretical contributions are also possible to apply on other, similar cases. One practical implication of the study is that transport operators should negotiate with ports to reduce the price charged for the loading and unloading of containers. These negotiations should give the ports incentives to investigate the possibilities to reduce costs in ports and change the price structures for coastal shipping. Another practical implication is that transport operators must evaluate the options for more environmentally friendly vessels that can be used on the route.

Keywords: coastal shipping, containers, barge, competitiveness, total cost of transport, logistic performance, environmental impact.

Glossary

Eurovignette	A road charge applied to heavy goods vehicles in Sweden.
FEU	Forty-foot equivalent unit. A measure of the size of a container.
Gross tonnage	A measure of the internal volume of a vessel.
HFO	Heavy fuel oil
ISO container	A container with a size standardised by ISO.
MDO	Marine diesel oil
Mooring	Fastening and securing a vessel alongside the berth.
PEC	Pilot exemption certificate
Pilotage	Assistance with navigating a vessel to ensure safe traffic at sea.
SCR system	Selective catalytic reduction system. A technique to reduce emissions of NO_x in exhaust gas from engines.
SECA	Sulphur emission control area
SSS	Short sea shipping
Stevedore	A person who works at the port and is responsible for the loading and unloading of vessels.
TEU	Twenty-foot equivalent unit. A measure of the size of a container.

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1. Introduction

This chapter starts with a background that introduces maritime transportation and coastal shipping, and why it is of interest to study this subject from a Swedish perspective. The scope of the project NÖKS II is described, with a special focus on the case that will be studied in this thesis. Thereafter, the purpose of this study is presented and further decomposed into research questions. The chapter ends with a presentation of the scope of this study.

1.1 Background

Sea freight is the dominating mode of transportation when it comes to freight transportation in the world. However, inland freight in the EU is strongly dominated by road transportation and in 2013, 75 percent of inland freight was transported by road and only seven percent by inland waterways (Eurostat, 2016). The use of inland waterways and coastal shipping in Sweden is even lower. Of the total domestic volumes transported in Sweden in 2014, three percent were transported using maritime transportation (Swedish Maritime Administration, 2016). The goods transported on waterways in Sweden are mainly bulk goods such as fuels, steel, mining and agricultural products (Swedish Maritime Administration, 2016). There are currently no containers transported with maritime transportation within Sweden, even though 13 million tonnes of container cargo was handled in Swedish ports in 2015 (Trafikanalys, 2016b). The containers are instead transported inland by road and rail to and from the ports. The Swedish Maritime Administration (2016) claim that the reasons for the low use of maritime transportation within Sweden are the low prices for road and rail transportation, in combination with customer requirements on high frequency, short lead time and high on-time reliability.

One argument often used by proponents of maritime transportation is the environmental benefits. But the thoughts on this matter diverge and several recent studies suggest that this assumption can be questioned (López-Navarro, 2014). The environmental performance of maritime transport in relation to road transportation is dependent on many factors, and a specific analysis must therefore be made to determine the environmental performance for a specific case (López-Navarro, 2014). However, the growing use of road transportation brings serious problems in urban centres and other areas with heavy traffic. Traffic congestions leads to longer lead times, higher operational costs, increased numbers of road accidents, environmental pollution and higher construction and maintenance cost of road infrastructure (Md Arof, 2015). A study done by Trafikverket (2015) shows that congestion exists also on the railways connected to ports in Western Sweden. Further growth of road or rail freight would therefore require large infrastructure developments, while the infrastructure needed for increased coastal shipping and inland waterways transportation already exists.

There have been discussions in the EU's transport policy paper where transportation by sea and inland waterways has been promoted (Douet and Cappuccilli, 2011). The European Commission state that sea transport is not only useful for carrying goods between continents, but a competitive and sustainable alternative to land transportation (European Commission, 2001). EU wants to strengthen the competitiveness of the maritime sector and have been promoting short sea shipping (SSS) both as an alternative to other modes and as part of an intermodal chain. SSS is defined by the European Commission as all movement of cargo by sea between European ports, and also between European ports and ports in non-European countries that have a coastline on the enclosed seas bordering Europe (European Parliament, 2015). Despite the efforts and financial support during the last 15 years, the level of modal shift to sea and inland waterways is according to Douet and Cappuccilli (2011) disappointing. In order to increase the use of maritime transportation, it must be seen as a competitive alternative by commercial players. According to Medda and Trujillo (2010), many actors wrongly see it as an old-fashioned mode of transport. Ng (2009) describe that freight transportation within Europe has been dominated by unimodal road transport because transhipment is considered to bring administrative complexity and long waiting times at terminals and ports. The European commission wants to prove this wrong, and show that transhipment to maritime transportation can be a competitive alternative.

1.2 Case description

NÖKS II is a project that fits very well with EU's objectives for increasing maritime transportation. The goal of NÖKS II is to develop waterborne transportation into an attractive, safe and green solution for freight transportation between Denmark, Sweden and Norway. The case that will be considered in this study is a part of NÖKS II and is a theoretical case of coastal shipping between Port of Uddevalla and Port of Gothenburg that has not yet been tested. There is a plan to demonstrate the case with a test run sometime during 2017, and this study serves as a pre-study to this demonstration. Today, goods are transported from different locations in Sweden to Port of Uddevalla by truck and rail and are there loaded into ISO containers. These containers, on average 42 forty-foot containers every week, are then transported by rail and road from Port of Uddevalla to Port of Gothenburg, where they are loaded onto vessels for further shipment to different destinations around the world. The suggestion that will be evaluated is to ship these containers along the Swedish coast from Uddevalla to Gothenburg instead of using rail and road as today.

As can be seen in Figure 1.1, the route is planned to go inshore. This means that there are some bridges to pass under, which limits the allowed height of the vessel. There is one part of the route, called Instörännan, which is a bit critical with a narrow passage and possibly shallow water. This part of the route must be passed in daylight, which sets some time constraints on the transportation. The whole route is approximately 102 km long and it is estimated that the trip will take nine hours. This means that the vessel will go at a very slow speed of six knots (just over eleven km/h). One possible vessel choice for this arrangement is a barge and a barge pusher, with a capacity of 56 FEUs and 14 TEUs. This vessel combination is currently considered as an option for the demonstration and possibly also a future permanent solution, and will therefore be used as a basis for calculations in this study. There are however other alternatives as well, which will be taken into consideration.

Figure 1.1. Map showing the route for the proposed coastal shipping solution between Port of Uddevalla and Port of Gothenburg.

The proposed coastal shipping solution would contribute to reduced congestion in the centre of Gothenburg, and also in the truck gate of the port. But other effects need to be evaluated. Since one of the strongest arguments for using maritime transportation is the environmental benefit, the environmental effects of the coastal shipping between Uddevalla and Gothenburg must be assessed. Moreover, if the solution should have a chance to become a permanent solution in the future, it must meet the requirements from the involved actors. This will include economic constraints, but also logistic requirements since the transportation between Uddevalla and Gothenburg is only one part of the whole transportation and must therefore be coordinated with the other activities in the transport chain.

1.3 Purpose of the study

The purpose of this study is to evaluate if and how coastal shipping of containers between Port of Uddevalla and Port of Gothenburg can be a competitive alternative to rail and road transportation.

1.4 Research questions

To answer the purpose, three research questions have been formulated to guide in the process. As mentioned earlier, performance indicators within economic, logistic and environmental performance will have to be considered in order to decide if a transport solution is competitive. Economic measurements can for example include costs for handling and costs for transportation. Examples of logistic performance indicators are reliability and flexibility, while environmental impact can be measured in for example emissions and energy consumption. This report is divided according to the three performance areas economy, logistics and environment, but it should be noted that the different performance areas are not completely independent of each other. For example, both logistic and environmental performance is likely to affect total costs. Before evaluating the performance of the theoretical case, it must be decided what performance indicators that should be assessed. This leads to the first research question.

> Q1: What economic, logistic and environmental performance would be required in order for coastal shipping to become a competitive alternative to road and rail transportation between Port of Uddevalla and Port of Gothenburg?

The first research question results in a list of requirements that shows what performance indicators that must be assessed and what requirements the coastal shipping solution must fulfil to become competitive. The theoretical case can then be evaluated and compared to the list of requirements.

> Q2: With the prerequisites of today, what performance requirements for the coastal shipping solution between Port of Uddevalla and Port of Gothenburg can be met?

The answer of the second research question shows that not all requirements can be met with the prerequisites of today. The last research question builds on this result and explores alternative arrangements and prerequisites that can make coastal shipping fulfil all the requirements.

> Q3: How should the coastal shipping solution between Port of Uddevalla and Port of Gothenburg be designed to meet the identified performance requirements?

To be able to answer the research questions, theoretical frameworks are built where existing literature on economic, logistic and environmental performance of coastal shipping is presented. The theoretical frameworks, together with empirical data, are then used to evaluate the competitiveness of a potential coastal shipping solution between Port of Uddevalla and Port of Gothenburg.

1.5 Scope

The study will consider activities regarding loading of containers onto the vessel, transportation of containers between the ports, and unloading of containers off the vessel.

1.6 Outline of the thesis

This thesis continues with a description of the methodology in the next chapter, followed by theoretical findings in chapters 3-6. The theoretical findings are thereafter used as a basis for analysing the interview results in chapter 7-11. In chapter 12, the findings of the study are discussed and in chapter 13 the final conclusions are presented.

2. Methodology

In this chapter it is described how the study has been conducted. The research design is explained, the research process is illustrated in a model and the chapter continues with a presentation of how the literature study, the data collection and the analysis have been conducted.

2.1 Research design

The research design of this study can be classified as a case study. Bryman and Bell (2015) state that a case study concerns the complexity and features of a specific case. The case should be carefully examined and later on analysed with the help of theory (Bryman and Bell, 2015). In this study, coastal shipping has been evaluated on the specific case Uddevalla-Gothenburg and data about specific features of this case have been gathered. However, since the coastal shipping solution is not used today, the case can be considered a theoretical case. Literature has been used to build theoretical frameworks which in turn have been used to analyse the gathered data about the case. An intense examination of the case has been done where data has been collected from many different involved persons and during a participant observation. Dubois and Gadde (2002) argue that using a particular case in this way is the best approach to understand the interaction between a phenomenon and its context, but they emphasize that reliance on theory is necessary to avoid basing conclusions on biased views from the case context.

2.2 Research process

In Figure 2.1, a model of this study's research process is presented. The first step in the process was to formulate a purpose for the study. An initial literature study was then started in order to get a broad overview of the subjects involved in the study. After gaining an initial insight in the case, a first set of research questions were formulated. With these questions as a base, the first interviews were planned and conducted. The interviews provided a great deal of information which was later analysed in an initial analysis. By doing this analysis, it became clear what information that was missing in order to answer the research questions which led to further literature studies. As more knowledge was gained, the research questions were reformulated into more precise questions but the overall purpose and direction of the study was kept. With the refined research questions as a base, further data collection and interviews were planned and conducted, the new information was analysed and then new literature was searched for again.

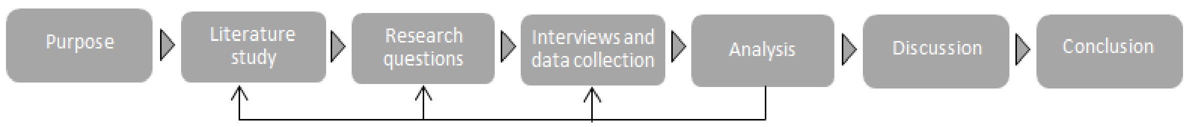

Figure 2.1. A research process model for the study.

To move back and forth between theory and empirical data in this way is a characteristic of a research approach proposed by Dubois and Gadde (2002), called 'systematic combining'. The authors argue that by using this approach, the researcher can get a better understanding of both the theory and the studied case than what is possible with a process consisting of strict subsequent phases. The research questions and the theoretical frameworks developed in this study have been continuously reoriented during the process, which according to Dubois and Gadde (2002) is necessary as unanticipated but related issues evolve along the way of a research process. The successively modification of the framework makes systematic combining an abductive approach, which is useful when the researcher's goal is to discover new things and refine existing theoretical models (Dubois and Gadde, 2002). The four steps of literature study, formulating research questions, planning and conducting interviews and data collection, and analysis were made in parallel. Gradually, as the gathered information was considered sufficient to be able to answer the research questions, a final analysis was conducted. The analysis was followed by a discussion about the outcome of the analysis, the practical and theoretical contributions, and the quality of the study. In the last phase, the conclusions of the study were finalized.

2.3 Literature study

A literature study was made in order to learn what is already known within the studied area and to create a theoretical framework for this study. The literature used has mainly been found through Summon Chalmers, a search engine for articles, books and other material available through Chalmers Library, and through articles recommended by supervisors and experts who have experience in the studied area. By reviewing the existing literature and bibliographies, major references for the research area were identified and used as main references in the beginning of the study, as recommended by Bryman and Bell (2015). The bibliographies in articles have, as suggested by Bryman and Bell (2015), been used as a source for additional relevant articles in the research area. Reports from organisations such as the Swedish Maritime Administration and Trafikverket have been used as sources of information and statistics concerning the Swedish freight sector.

Like Bryman and Bell (2015) recommend, some keywords were worked out before starting the literature search, so that relevant references could be found through the search engines. Examples of such keywords were: coastal shipping, short sea shipping and sea transport of containers. More keywords were then added along the way as the study developed in specific directions. These specific keywords were for example: port costs, costs of loading and unloading containers, and environmental performance of sea transport. The literature has been reviewed critically by comparing the conclusions from many published articles and taking into consideration in what contexts the studies were done. What year and in what journal the article has been published has also been used as a criteria of selection.

2.4 Data collection

This section describes the data collection, the different methods that have been used and why these were considered appropriate for this study.

2.4.1 Interviews

Information about the case was mainly gathered through interviews. This was considered an appropriate method since there are several individuals involved in the case that have extensive knowledge within maritime transportation in general, and container transportation on the Uddevalla-Gothenburg route in particular. Bryman and Bell (2015) discuss two types of interviewing: quantitative and qualitative interviewing. For this study, qualitative interviewing was considered more appropriate since it allows the interviewees to present their own thoughts and reflections rather than just answering the researchers' precise questions. To gather as much relevant information as possible and allow for a broader understanding of the case, interviewees' thoughts were of much interest during the interviews. Qualitative interviewing is a good method when rich and detailed answers are wanted, and as opposed to quantitative interviewing, it allows more freedom in the discussion regarding what questions to ask and the order of them (Bryman and Bell, 2015).

The type of interviews used was mostly semi-structured. Semi-structured interviews mean that an interview guide is prepared before every interview with quite specific topics, but the guide does not have to be followed completely during the interviews (Bryman and Bell, 2015). When interviews were held, the broad topics of the interview guide were discussed but the order of the questions was adjusted according to the discussion. Depending on what the interviewee answered to previous questions, new questions arose which were not part of the guide or the following questions were modified. This is according to Dubois and Gadde (2002) an appropriate approach when the researcher wants to discover new data and new dimensions of the problem. For some interviews, all questions were not discussed and in these cases the remaining questions were asked by mail or at a later interview. To not ask every question in the interview guide is, according to Bryman and Bell (2015), a characteristic of an unstructured interview. In this manner, the interviews held during the study were mostly semi-structured but with some unstructured influences. Bryman and Bell (2015) state that most qualitative interviews are a mix of unstructured and semi-structured interviews, but they often lean more towards one of the two types.

The interviews that were held are presented in Table 2.1. The dates and lengths of the interviews, as well as the positions of the interviewees and the companies they work for are presented.

Table 2.1. Presentation of the interviews conducted during the study.

Date	**Length**	**Position**	**Company**
2017-02-01	1 h	Project developer	SMTF
2017-02-02	2 h	Business Development Manager and Commercial Manager Rail Senior Manager Business Development	APM Terminals Gothenburg AB Port of Gothenburg
2017-02-09	2 h	Marketing- and Forwarding Manager	Port of Uddevalla
2017-03-13	1 h	Professor of Maritime Transport Management and Logistics	University of Gothenburg
2017-03-14	1 h	Business Development Intermodal and Short Sea	CMA CGM
2017-03-17	1 h	Project Manager	SSPA
2017-03-17	0.5 h	Project Manager	SSPA
2017-03-20	1 h	Area Manager, Gothenburg Maritime Pilot Area	Swedish Maritime Administration
2017-03-22	1 h	Marketing- and Forwarding Manager	Port of Uddevalla
2017-03-23	1 h	Project developer	SMTF

Before every interview, an interview guide was created to make sure that valuable information could be gathered. In the beginning of the study, very broad questions were prepared, both in order to understand the case better and to understand what role each interviewee had in the case. After the first three interviews, more structured interview guides were prepared. According to Bryman and Bell (2015), interview guides should always be based on what the researcher needs to know in order to answer each research question. Also, to divide questions into different categories is a good way to make sure the questions are in an appropriate order (Bryman and Bell, 2015). Broad categories for the interview guides were decided based on the research questions and topics within each category were decided based on areas studied during the literature study or areas related to the actual container flow.

The broad categories of economic, logistic and environmental performance remained the same for all interviews but the questions within each category changed slightly depending on what information that had already been gathered and the interviewees' areas of expertise. The interviewees' job positions and potential knowledge areas were looked up before creating questions for the interview, but this information was also confirmed or adjusted during the interviews where the interviewees were asked to talk about their jobs. According to Bryman and Bell (2015) it is advantageous to be familiar with the interviewees' positions and work environments in order to better understand their responses to questions. As can be seen in Figure 2.1, the literature study was continued and research questions were reconsidered after the first interviews. Since the interview guides are supposed to help to gather information for answering the research questions, questions in the interview guides were slightly changed as the research questions were reconsidered. In Appendix A an example of an interview guide used in this study is presented.

To make sure that as little information as possible was lost from the interviews, all interviewees were asked if the interview could be recorded. In most cases, the interviewees approved but in two cases the interviewees felt hindered to share sensitive information if the interview was recorded and thus the interview was not recorded. According to Bryman and Bell (2015), recording interviews is advantageous since it allows researchers to repeat interviewees' answers and by that be able to make more thorough examinations of the information gathered during the interview. Bryman and Bell (2015) also suggest transcribing recorded interviews but since this is very time consuming, as detailed notes as possible were taken during the interviews instead and only when something was unclear after the interviews, the record was listened to and the notes were adjusted. All interviewees were, in the beginning of every interview, informed about that if any information was too sensitive to be part of the written report, they should clearly state that.

After each interview, the notes were compiled into more structured documents. By rewriting the notes from the interviews, the information was processed a second time which was helpful in understanding the interviewees responses better and to find out what information that had to be gathered in later interviews. The majority of the information gathered during the interviews was qualitative data, but quantitative data was also gathered. However, to avoid misunderstandings, quantitative data was mostly gathered through emails in written form.

2.4.2 Participant observations

According to Bryman and Bell (2015), participant observation is considered to be a helpful method when examining a case in detail. Observations are useful to understand a specific case from the viewpoint of the people working with it on a daily basis and to understand the specific language and terms that are used in the organization (Bryman and Bell, 2015). During the study one observation was made at the Port of Uddevalla. The observation was useful in getting a broad overview of the port and the different quays where vessels are loaded, unloaded or parked. The observation resulted in a better understanding of the size of the port and what products and types of vessels that are handled at the different quays. Bryman and Bell (2015) states that by doing observations, additional information can be gathered which otherwise is difficult to get from interviews. An interviewee may consider some information to be too basic to discuss at an interview or he/she may be reluctant to talk about activities working poorly. The observation at Port of Uddevalla was useful in gathering additional information about the case that had not been collected during interviews.

2.4.3 Secondary data

In addition to interviews, data has also been gathered through some secondary sources. Bryman and Bell (2015) state that both public and private organizational documents can be of interest for researchers in order to obtain background information and history about companies. In the study, company specific information has been obtained through the involved companies' web sites and through written material distributed at the interviews, such as presentations and catalogues.

2.5 Analysis

Bryman and Bell (2015) emphasize that it is important to plan the data analysis before collecting data, since the choice of analysis techniques affects in what form and size the samples of data should be collected. The data analysis for this study was therefore initially planned quite early in the research process, before starting the data collection. It then continued as an iterative process where further data analysis was planned before collecting new data.

2.5.1 Interview data analysis

The analysis of the qualitative data collected through interviews and the participant observation was started directly after every data collection occasion. The notes taken during the interviews and the observation were reorganized and sometimes rewritten directly afterwards or the next day. If something appeared to be unclear in the notes, the recordings from the interviews were listened to or follow-up emails were sent to the interviewees or responsible personnel at the observed site. In this way, the risk for misperceptions could be minimized. While going through the information gathered from interviews, short notes and memos were written when ideas of preliminary analysis categories and relationships between collected data were found. This categorization procedure is recommended by Maxwell (2013) since it helps to capture ideas and facilitate analytical thinking.

When structuring the collected data, categories in three different levels were determined. The highest level was based on the research questions and provided a good division of the collected data in order to facilitate the analysis. The second level was based on the three broad, predetermined categories: economic, logistic and environmental factors. Maxwell (2013) call this type of categories 'organizational categories' and argue that they can be used as headings for larger chapters, but that they will not facilitate analysis very much since they are usually quite broad. The lowest category level was based on concepts and properties identified from the interview data that seemed important for the study. These concepts and properties were identified by rearranging the interview data into groups of similarities and differences which resulted in several subcategories. These subcategories are referred to by Maxwell (2013) as substantive or theoretical, depending on if they are based on a participant's concepts or derived from theory and the researcher's concepts. Both of these types of categories have been used during the data analysis in this study and what they have in common is that the categories are not known before the data collection. The structured interview data was then used to analyse each of the three research questions.

2.5.2 Analysis of the first research question

When the first research question was analysed, information from interviews together with theory was used to decide the requirements for a competitive coastal shipping solution between Port of Uddevalla and Port of Gothenburg. The process for the analysis is illustrated in Figure 2.2.

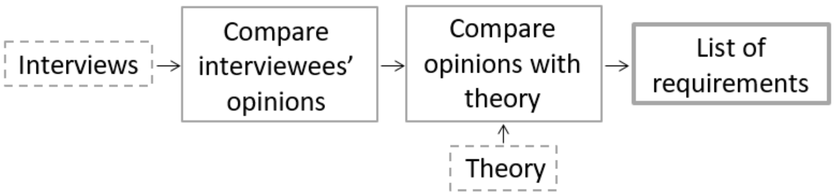

Figure 2.2. Process for analysing research question one. Input is illustrated with dashed lines, the process steps for the analysis have solid lines, and the result of the analysis is marked with a bold line.

The categorization made in the previous interview data analysis was helpful in finding the most important requirements since opinions from many interviewees could easily be compared. Connections between different individuals' opinions were searched for since this, according to Maxwell (2013), is a good strategy for analysing data and for combining statements into a comprehensive context. In order to ensure that the requirements identified from interviews were reasonable, they were also compared with factors identified in theory as important for transport buyers. As described in section 2.4.1, questions asked during interviews were partly based on categories found in literature and partly based on categories related to the actual container flow. This means that the identified performance factors in the list of requirements are both a result of theoretical findings and interviews. The list of requirements that resulted from this analysis provided the result for the first research question and was used as a basis for the following analysis concerning research question two and three.

2.5.3 Analysis of the second research question

When the list of requirements had been created, the analysis of what performance requirements that could be met with the prerequisites of today was started. The process is illustrated in Figure 2.3.

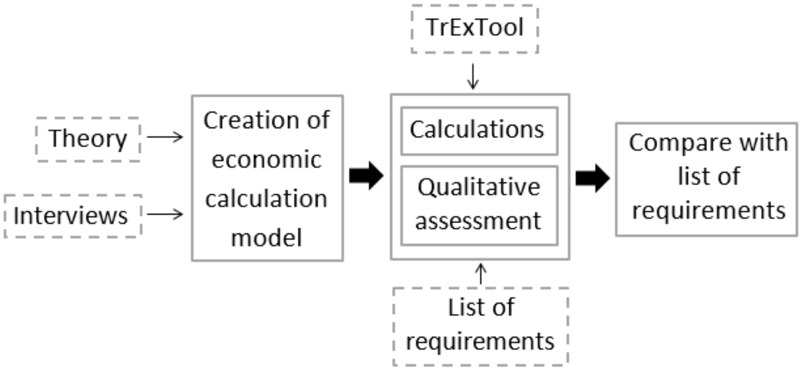

Figure 2.3. Process for analysing the second research question. Input is illustrated with dashed lines and process steps for the analysis have solid lines.

The first step of the analysis was to create an economic calculation model. Theory together with information from interviews was used to find what cost items to include (see a further description of the model in section 2.5.4). Thereafter, economic and environmental calculations and qualitative assessment were made to evaluate the performance of the coastal shipping solution. In addition to the economic calculation model, a calculation model for environmental performance called TrExTool was used (see section 2.5.5). The two calculation models provided quantitative results about economic and environmental performance but quantitative data about logistic performance could not be gathered since there is no coastal shipping on the studied route today. Therefore, the logistics performance could only be assessed using qualitative data. The list of requirements identified what factors to evaluate against today's prerequisites regarding economic, logistic and environmental performance. The result from the calculations and qualitative assessment was then compared with the list of requirement to identify what requirements that could and could not be met.

2.5.4 Creation of an economic performance calculation model

An economic performance calculation model was created in Excel to quantitatively evaluate the studied case. The model with its different cost items is presented in Appendix B. To decide what cost items to include in the model, both theory and interview data was used. From theory, common costs for shipping were identified while the interviews provided information about specific costs for Swedish coastal shipping. The different cost items were then categorized into different groups based on if the costs were related to transport costs or port costs since these categories were identified in the theoretical framework about economic performance.

The model consists of three Excel sheets. One sheet for input data, one sheet where calculations are done automatically and one sheet that presents the results. In the input data sheet, the user chooses if the vessel will be rented or bought and what model that should be used for the calculation of fairway dues (2017 or 2018). Then the user fills in all the input data for the relevant case. The total cost for the transport arrangement can then be found in the results sheet. The cost is divided in costs for handling and costs for transportation, and is presented both in cost per transport unit and for the whole transportation. The distribution between the different cost items are shown in pie charts in the results sheet. The user can fill in the transport and handling costs for other transport modes in order to make a comparison and see the results in a diagram. It is also possible to change volume and frequency directly in the results sheet, which makes it easy to see how changes in these parameters impact the final results.

The economic performance calculation model is specifically developed for the studied case but since the same cost items apply to Swedish coastal shipping in general, it can be used for other cases as well. Quantitative data used to fill in the model was mostly gathered through interviews with people involved in the transportation and port handling. Vessel-related data was gathered through the barge owner’s website and data about fairway dues and pilotage fees was gathered through the Swedish Maritime Administration’s website. The economic performance model resulted in several cost diagrams which were later used in the analysis of research question two.

2.5.5 Environmental performance calculation model

In order to compare the environmental performance of coastal shipping, road and rail transport, a tool called TrExTool 2.0 was used for calculations of energy consumption and emissions for all three transport options. TrExTool was considered to be a suitable tool since it estimates both energy consumption and emissions of all the relevant substances, and it is possible to compare different modes of transport. The input data used for the calculations was gathered through interviews and the data can be found in Appendix C. The results of the calculations can be found in Appendix D.

TrExTool has a number of predetermined vehicles to choose from. The “Truck with trailer 40-50t - Max Load 33t” was chosen for road transport since this truck can carry a forty-foot container with the weight of 30 tonnes which is studied in this case. The trucks are estimated to belong to Euro V since one of the interviewees who is familiar with the road transports from Port of Uddevalla stated that vehicles of Euro IV, V and VI are currently used. For the calculations of rail transport, the “Large Train - 1500 Gt” was the option that best suited the volumes and was therefore used in the calculations. The amount of goods to be transported was set to 1500 tonnes and 2895 m3, which corresponds to 50 forty-foot containers with the weight of 30 tonnes each.

TrExTool has no vessel that perfectly matches the barge and barge pusher considered in this case. A larger vessel, “Container-Coastal-5000 dwt-571 TEUs” was therefore used for initial calculations and the results were adjusted to better represent the barge. The load factor of the barge when carrying 50 forty-foot containers is 63 % by weight and 80 % by volume. These percentages were therefore used for the vessel in TrExTool as well. The fuel consumption of the barge pusher with the planned load and speed is known to be 250 l/h, while the fuel consumption of the vessel chosen in TrExTool was 309 l/h with the same load factors and speed. This means that the barge’s fuel consumption is 81 % of the fuel consumption of the vessel chosen in TrExTool. Therefore, the energy consumption and the levels of emissions were also estimated to correspond to 81% of the levels of the vessel chosen in TrExTool. The output data for all three modes of transport formed the basis for analysis of the environmental performance. The calculations are based on some assumptions and TrExTool does not have exactly the vessel considered in this case study. The result could have been a bit different if making other assumptions or using another tool for calculations, but the result of TrExTool can be seen as a good indication of the actual values for energy consumption and emissions.

2.5.6 Analysis of the third research question

In Figure 2.4, the method for analysing the third research question is illustrated.

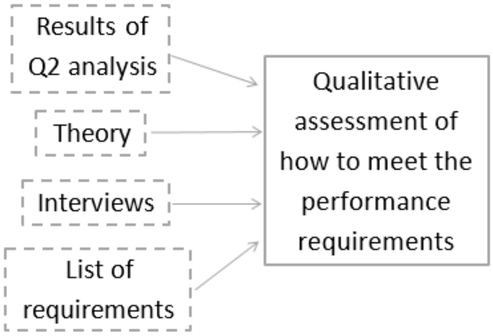

Figure 2.4. Model describing the method used for analysing the third research question. Input to the analysis is illustrated with dashed lines.

The results from the analysis of the second research question were used as input and a starting point for this analysis. The results showed what requirements that could not be fulfilled and hence what areas that would be further analysed. Theory and interview data was used to find possible ways to design the coastal shipping solution in order to meet all requirements. While analysing the design of the transport solution, the list of requirements developed during the analysis of the first research question was used in order to make sure that the proposed design would not violate any of the already fulfilled requirements. A qualitative assessment was then conducted to find out how the coastal shipping solution should be designed in order to meet all performance requirements.

2.6 Quality of the study

Validity and reliability are two commonly used criteria when evaluating the quality of a quantitative study (Denscombe, 2014). But for a qualitative study, these criteria can be difficult to apply because of the differences between qualitative and quantitative studies. Measurements are for example not common in qualitative studies, and validity can therefore not be applied in the same way as for quantitative studies (Bryman and Bell, 2015). The researcher is usually closely involved in a qualitative study and will therefore affect the data collection and analysis, which makes it unlikely that another researcher would have reached exactly the same conclusions (Denscombe, 2014). The concept of replication is also difficult to apply to qualitative studies, since it is almost impossible to replicate a social setting where a qualitative study is conducted (Denscombe, 2014). Bryman and Bell (2015) also mention that there are not always absolute truths in the social world, which means that several different conclusions might be correct. But even if qualitative studies cannot be examined in the same way as quantitative studies, the quality of a study must be evaluated in some way. Denscombe (2014) and Bryman and Bell (2015) suggest that the trustworthiness of a qualitative study is judged using the four criteria credibility, dependability, transferability and confirmability. These criteria are related to validity and reliability, but adapted for qualitative studies. The quality of this study has been evaluated using these four criteria and is further presented in section 12.4.

3. Theoretical findings on the economic performance of coastal shipping

Economic performance is often one of the first aspects thought of when investigating freight solutions. This section presents the findings of earlier research within economic performance of coastal shipping and investigates the cost items that constitute the total cost of a coastal shipping transportation. The chapter ends with a theoretical framework summarizing the findings, which is later used in the analysis.

3.1 The importance of total cost when selecting a transport solution

The Swedish Maritime Administration (2016) claim that transport price is often the single most important factor when deciding a transport solution. Yang et al. (2014) and Everett and Kittel (2010) likewise conclude that cost, together with a reliable transportation time, are the most crucial factors and that a coastal shipping arrangement must be economically viable if it should be considered as a realistic transport solution. Furthermore, Baindur and Viegas (2011) mean that consignors using road transport are only willing to switch to sea or rail transport if the transport costs of these alternative modes are 30-50 % lower than road transport. Paixão and Marlow (2002) have a more precise estimate and claim that consignors are only willing to switch from road to sea transport if the transport cost, from door to door, is 35 % lower than road transport. The reason why the cost has to be that much lower is the additional inventory costs that sea transport incurs, due to a longer lead time (Paixão and Marlow, 2002). According to Arvis et al. (2010), transport buyers are often willing to pay a premium price for a more reliable transport solution. The authors state that rail transport is the least reliable mode and transport buyers are therefore often willing to pay more for road and sea transport than for rail transport.

3.2 Port costs

Costs incurred at ports often make up a large share of the total costs in SSS. According to Paixão and Marlow (2002), port costs can represent as much as 70-80 % of the total costs of a short distance sea transport. When the Swedish Maritime Administration (2016) did case studies to analyse the potential of developing coastal shipping and inland waterway transportation, they found that port related costs made up 36-62 % of the total costs for the transportations. In the case with the shortest distance (100 km), the port costs made up the largest share of the total costs.

3.2.1 Port charges

When vessels call at a port they have to pay a certain port charge that is used to finance the port (Baindur and Viegas, 2011). The port charge varies between ports and according to Baindur and Viegas (2011), the underlying cost structures for port charges are often not transparent. The

Swedish Maritime Administration (2016) claim that ports' price structures to a large extent decide the competitiveness of SSS and they state that the price structures are highly influenced by the geographical monopoly a port may have and by the high costs associated with equipment, facilities and personnel at the port.

Paixão and Marlow (2002) mean that investment and maintenance costs of ports are lower than the corresponding costs of road and rail infrastructure. Perakis and Denisis (2008) are of the same opinion and state that capital costs of short sea terminal infrastructure are much lower than the costs of expanding and maintaining road transport infrastructure. According to Paixão and Marlow (2002), building road and rail infrastructure require huge investments and this land infrastructure is more extended than the sea infrastructure. The only physical land area that sea transport requires is ports. While for land transport, investments must not only be made in highways and railway lines, but also in tunnels and bridges (Paixão and Marlow, 2002). Despite the higher costs of road and rail infrastructure, Baindur and Viegas (2011) state that there is no similar charge as the port charge for using road or rail transport.

3.2.2 Cost of loading and unloading containers

According to Lu and Yan (2015), handling costs vary significantly between different ports but they often make up a large share of the total costs of sea transport. The Swedish Maritime Administration (2016) state that in order to make coastal shipping economically competitive, it is very important to have a cost effective handling in ports. Baindur and Viegas (2011) mention high handling costs as one of the factors that makes SSS an unattractive transport solution. Lu and Yan (2015) further argue that when having high handling costs, the advantage of sea transport is weakened and it is therefore important to reduce handling costs in order to increase the use of coastal shipping. Johnson and Styhre (2015) claim that when a vessel calls at a port regularly, the efficiency of the loading and unloading activities can be increased since the crew on board the vessel gets to know the port procedures better and the stevedores get more acquainted with how to load and unload the vessel.

According to the Swedish Maritime Administration (2016), handling costs in Swedish ports are to a large extent made up of personnel costs. These personnel costs are difficult to change since they in many cases are controlled by outdated collective labour agreements (Swedish Maritime Administration, 2016). Handling costs in ports are also affected by equipment costs. The acquisition of handling equipment for container handling in ports is a large investment and in order to make it more economically justifiable, a high utilization and a large scale is necessary (Swedish Maritime Administration, 2016). Paixão and Marlow (2002) state that handling efficiency can be decreased if handling equipment is used incorrectly or if the equipment does not fit the type of cargo handled. This decrease in efficiency also affects the handling costs negatively (Paixão and Marlow, 2002).

3.2.3 Mooring costs

When vessels approach a port they must be fastened and secured alongside the berth. This operation of tying up the vessel is called mooring (House, 2007). Schelfn and Östergaard (1995) state that it is important to have a safe mooring operation in order to avoid accidents. There have been several incidents during mooring of crude-oil carriers resulting in both damages to the port infrastructure and pollution. It is therefore important to be aware of all factors that affect the safety of mooring, such as the size and type of vessel, available mooring equipment, the port's physical conditions and weather conditions (Schelfn and Östergaard, 1995). A safe mooring operation is also dependent on the people involved. The crew on board the ship must cooperate with stevedores and everybody involved must be familiar with the factors affecting the safety of the mooring (Schelfn and Östergaard, 1995). The stevedores that perform the mooring operation must be paid and a mooring fee is therefore charged from the vessel that is calling at the port.

3.2.4 Administration costs

Sea transport is characterized by a lot of administrative work. Medda and Trujillo (2010) highlights the great amount of documentation regarding for instance cargo operations, inspection of ship safety and cargo declaration that must be handled every time a vessel calls at a port. According to Baindur and Viegas (2011), there is often a lack of standards for administrative work in ports and different ports have different methods for handling the documentation. The administrative work is increasing which also leads to increased transaction costs that affect shipping companies negatively (Baindur and Viegas, 2011). Paixão and Marlow (2002) even mention the excessive amount of paperwork and the resulting high administrative cost as a barrier for the success of SSS.

3.3 Transport costs

Costs incurred during transportation between ports are related to the vessel, the fuel consumption and different fees. These cost items will be further presented in this section.

3.3.1 Vessel costs

Vessel-related costs are dependent on what type of ship that is being used and what type of cargo that is being carried (Marlow and Paixão Casaca, 2007). When transporting large volumes of goods over long distances, sea transport is a cost effective alternative and provides economies of scale (Swedish Maritime Administration, 2016). The Swedish Maritime Administration (2016), state that there are few actors in Sweden that need to transport very large amounts of goods nationally. This means that the large scale transportation that SSS provides as an advantage over road and rail transportation is not asked for by transport buyers, and the possible economies of scale are not utilized. For small goods volumes, the cost structure of SSS makes this transport solution less attractive according to the Swedish Maritime Administration (2016).

How vessel costs are categorized varies between different studies. In a study by Ng (2009), the vessel-related costs were categorized as costs for renting a vessel, costs for the crew on board the vessel and miscellaneous vessel costs. In another study performed by Sambracos and Maniati (2012), vessel costs were categorized in a more detailed way. First, the acquisition cost was considered in two different scenarios, one where a new vessel was purchased and another where a second hand vessel was purchased. Thereafter, costs for maintenance and repair, insurance and personnel were considered.

3.3.2 Fuel costs

Fuel costs often make up a large share of the transport costs of sea transport. Sambracos and Maniati (2012) state that in their study, fuel costs made up the main voyage cost and in the studies made by the Swedish Maritime Administration (2016), fuel costs made up between 10 and 25 % of the total costs of coastal shipping. Jafarzadeh and Utne (2014) also agree on that fuel costs can be a considerable share of the operational costs of sea transport and the authors highlight that fuel prices are increasing and fluctuating. High fuel costs together with the instability of fuel prices indicate the importance of trying to reduce fuel consumption in SSS (Jafarzadeh and Utne, 2014).

One way to reduce fuel consumption is to use the concept of slow-steaming where vessels go at a lower speed in order to save fuel (Notteboom and Cariou, 2013). Notteboom and Cariou (2013) state that slow-steaming is becoming more and more common in container shipping and in addition to savings in fuel costs, slow-steaming also reduces the air pollution from ships. Drewry (2011) claims that the reduction in fuel consumption from slow-steaming is largely dependent on the vessel, but a reduction in speed from 26 to 22 knots can more than halve the fuel cost for a vessel transporting 5000 TEUs. It is, however, important to notice that the slower speed will increase the transport time and there will therefore be a trade-off between time and cost of the transport (Ferrari et al., 2015). Woo and Moon (2014) claim that the reduced costs from slow-steaming are most apparent at high speeds, since the relation between speed and fuel consumption becomes inelastic at low speeds. This means that even if the speed is reduced by the same degree, the fuel consumption will not decrease as much as in the higher, more elastic speed range. When the voyage speed is slower, the total cost for the transportation can instead increase due to that the increased transport time brings other costs that outweigh the savings in fuel consumption (Woo and Moon, 2014).

Fuel costs are dependent on the type of fuel used. The studied case belongs to a Sulphur Emission Control Area (SECA) where fuels used cannot contain more than 0.1 % sulphur (IMO, 2017b). The prices of these fuels are higher than for fuels with higher sulphur levels, and hence fuel costs for shipping companies operating within SECA are higher than for those operating outside of SECA (Antturi et al., 2016).

The transport distance is another factor affecting fuel consumption and fuel costs. According to Perakis and Denisis (2008), the average distance for SSS in Europe is 1385 km. The authors claim that the fuel consumption per ton-mile of cargo is lower for sea transport than for road transport and one ton of cargo can be transported more than ten times longer distance if using a barge instead of a truck and the same amount of fuel. Even though sea transport implies lower fuel costs per kilometre, road and rail transports are often more competitive on short distances due to much lower handling costs (Swedish Maritime Administration, 2016). Generally, the advantages of shipping are greater with increased distance (Perakis and Denisis, 2008).

3.3.3 Fees

The fees to be considered in Swedish coastal shipping are fairway dues and pilotage fees. The case studies conducted by the Swedish Maritime Administration (2016) showed that pilotage and fairway fees together made up on average 7 % of the total transport costs, whereof pilotage fees made up the largest share. Pilotage fees are either paid for the whole distance travelled or for certain parts of it, depending on the specific route. To avoid paying for pilotage in every trip, a pilot exemption certificate (PEC) can be applied for (Swedish Maritime Administration, 2016). The captain is then allowed to drive the distance without a pilot and the pilotage fee can be avoided. The cost of the PEC differs from case to case and is dependent on the route's distance (Transportstyrelsen, 2012).

The incomes from fairway dues in Sweden are used for operation, maintenance and development of fairways and other infrastructure related to shipping. The Swedish Maritime Administration (2016) states that in order to make coastal shipping more competitive in Sweden, it might be necessary to temporarily reduce the pilotage and fairway dues or to offer support in other ways. However, the regulations about a competitive market in the EU must still be complied with and it is important to evaluate the effect of such support measures on the competitiveness of other transport modes (Swedish Maritime Administration, 2016). In January 2018 a new fee model for fairway dues is planned to take effect in Sweden. The new model is supposed to be simpler and fairer than the current one and it is supposed to be easier to estimate costs when choosing a transport solution (Swedish Maritime Administration, 2016). All vessels will be subject to the same judgement criteria when deciding fairway dues and discounts that today apply to certain geographical areas will be reduced or eliminated (Swedish Maritime Administration, 2016). The new fees will, to a greater extent than today, be based on the size of the vessel, and less on the weight of the cargo. The fee model will also provide a discount to vessels being more environmentally friendly according to the "Clean Shipping Index". According to the Swedish Maritime Administration (2016), the new fee model is likely to have a negative impact on current coastal shipping.

3.4 External costs

External costs are costs that appear because of negative externalities, which are not automatically paid for by the responsible company, but by the society (Ricardo-AEA, 2014). It can be environmental externalities such as pollution, infrastructural externalities such as wear and tear on roads, and social externalities such as accidents in traffic. The interest for transportation externalities has grown and according to Lu and Yan (2015), it is very important to include external costs in cost calculations of transport solutions. Externalities are situation-dependent; the external effect of a transportation activity will be different depending on where and when the transportation takes place, which makes it difficult to quantify the external costs (Perakis and Denisis, 2008). Assumptions are required in order to estimate external costs and uncertainties and differences in these assumptions make it difficult to make comparisons between different transport modes (Perakis and Denisis, 2008). However, organisations such as the Swedish Transportation Administration present recommendations every year for how to calculate external costs (Trafikverket, 2016). Several studies show that the total external costs of sea transport are lower than for road transport (Lu and Yan, 2015; Md Arof, 2015; Galati et al., 2016), but a study made by the Swedish Maritime Administration (2016) shows that the external costs of rail transport are even lower than for sea transport.

Parts of the external costs of transport are already internalized through different taxes and fees (Swedish Maritime Administration, 2016). By internalizing external costs, transport users can better take into account the external costs when making transport decisions (Ricardo-AEA, 2014). According to the Swedish Maritime Administration (2016), all external costs related to the use of infrastructure are today internalised in Swedish maritime transportation, while external costs related to environmental effects are not internalised. This differs from road transportation, where parts of the external costs for environmental effects are internalised through diesel taxes, but infrastructural costs for roads are often external (Swedish Maritime Administration, 2016). Heavy trucks in Sweden pay vehicle tax, eurovignette and diesel tax and the total diesel taxes for trucks are 6.25 SEK/litre when the fuel is fully fossil (Kågesson, 2011; Swedish Maritime Administration, 2016). For sea transport on the other hand, there are no fuel taxes but there are other fees such as fairway dues and port charges which internalize the external infrastructural costs. Regarding rail transport in Sweden, the Swedish Maritime Administration (2016) claim that the external costs are lower than for both road and sea transport but the level of internalized external costs is only 38 % for rail, compared to 58 % for sea transport and 70 % for heavy trucks with trailers.

The European Commission is working towards internalizing all external costs for all goods transportations and it is likely that a larger share of the external costs will be internalized in the future (Ricardo-AEA, 2014). According to the Swedish Maritime Administration (2016), external costs for goods transports in Sweden will be fully internalized for all transport modes in a few years. Many authors mention that sea transport has the lowest non-internalised external costs per tonne-kilometre compared to rail and road transport and a higher internalisation level for all transport modes would be beneficial for sea transport (Sambracos and Maniati, 2012; Lu and Yan, 2015; Galati et al., 2016). Moreover, Paixão and Marlow (2002) state that road transport’s high non-internalised external costs create an unfair market situation where road transport is cheaper than it should be and an artificial demand is created for road transport. However, the Swedish Maritime Administration (2016) claim that external costs from road transportation has decreased in recent years due to lower emission levels from new trucks and with this development in consideration it is not certain that a higher internalization level will be beneficial for sea transport.

3.5 Theoretical framework of the economic performance of coastal shipping

The theory regarding the economic performance of coastal shipping which has been presented in this chapter is summarized in the theoretical framework shown in Figure 3.1.

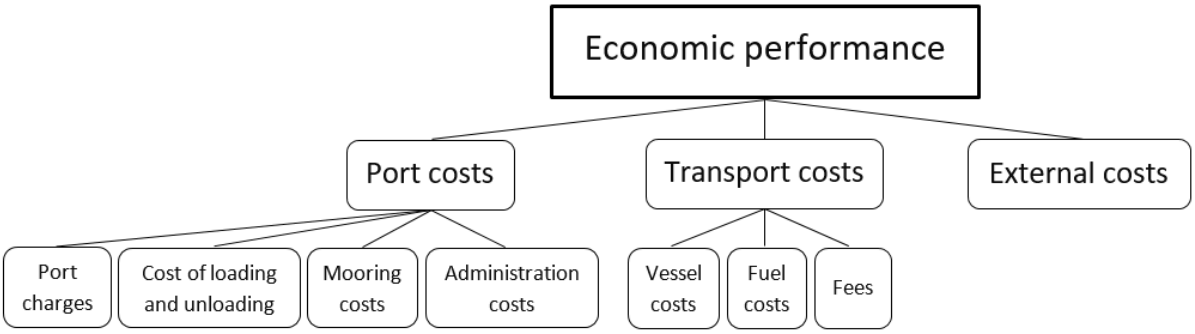

Figure 3.1. A theoretical framework of the economic performance of coastal shipping.

There are three main costs affecting the economic performance: port costs, transport costs and external costs. These costs are in turn affected by several different cost items which are illustrated in the lowest level in the theoretical framework.

4. Theoretical findings on the logistic performance of coastal shipping

Depending on what types of goods and what volumes that need to be transported, transport buyers choose different transport modes according to the transport modes' relative advantages and disadvantages. Even though price is often what ultimately makes the buyer choose a certain transport solution, lead time, reliability, flexibility and frequency are logistic factors that transport buyers are increasingly interested in (Swedish Maritime Administration, 2016).

4.1 Lead Time

The total lead time for a transport solution from door to door is usually longer when using sea or rail transport than it is for road transport. This is because sea and rail transport often require intermodal transport to complete the whole route and hence transhipments are necessary (Paixão and Marlow, 2002). To reach a short lead time is usually not a priority when it comes to maritime transportation (Perakis and Denisis, 2008; Swedish Maritime Administration, 2016). As mentioned in section 3.3.2, there is a trade-off between transportation time and fuel cost in sea transportation, as the fuel consumption increases with high speed (Notteboom and Cariou, 2013). But a longer transportation time due to slow speed can make it necessary to add additional vessels in order to keep the frequency of service, and it adds additional inventory cost for shippers due to tied up capital (Notteboom and Cariou, 2013). Paixão and Marlow (2002) argue that the increased inventory costs are one reason why shippers choose unimodal transport (often road-haulage) instead of an intermodal chain including SSS.

4.2 Reliability

On-time reliability is an important performance measure, sometimes even pointed out as the most important of all measures (Perakis and Denisis, 2008; Md Arof, 2015). The Swedish Maritime Administration (2016) state that customers are not willing to change to a different transport mode unless the service and on-time reliability is on the same level as their current transport arrangement. The reliability of SSS is generally considered to be low, especially when it comes to departure and arrival times in ports (Medda and Trujillo, 2010), which makes it difficult to meet the Just-In-Time requirements of the supply chains today (Trujillo et al., 2011). Morales-Fusco et al. (2013) state that a transportation chain that includes SSS is considered less reliable by the shipper than a transportation chain without SSS. Galati et al. (2016) are of the same opinion and argue that introducing SSS in a transportation chain makes it more complex, and therefore it is seen as less reliable. Furthermore, Alemán et al. (2015) claim that ports are considered unreliable and that the need for fast cargo handling cannot be met due to obsolete infrastructure and handling procedures. However, the Swedish Maritime Administration (2016) does not agree with this opinion and instead argue that in some cases the high reliability of shipping can make up for the longer transport time.

Weather conditions is something that reduces the reliability of water transportation, as no other transport mode is as dependent on weather conditions (Baindur and Viegas, 2011). Lam and Lassa (2017) have studied maritime risks connected to weather extremes and propose a risk assessment framework. They argue that there is an increased risk in maritime transportation due to extreme weather events, and it is therefore of importance to assess port and cargo risks. Road transportation is often regarded by customers as the most reliable mode (Paixão and Marlow, 2002). But the travel time, and consequently also the on-time reliability, of road transportation can be negatively affected by congestion on the roads (Medda and Trujillo, 2010).

4.3 Flexibility

Flexibility refers to a system's ability to change or react, preferably with low or no changes in effort, such as cost or time (Lagoudis et al., 2010). There are at least 49 different types of flexibility defined in literature, often concerning manufacturing (Naim et al., 2006). Naim et al. (2006) focus on transport flexibility and have identified five types of flexibilities that determine the performance perceived by the customers: product, mix, volume, delivery and access flexibility. Product and mix flexibility refer to the ability to offer new transport services and change the current services, for example by offering new destinations and other modes of transportation. These types of flexibility are not relevant for this study, since the focus is on one single route and the purpose is to evaluate coastal shipping only. Volume, delivery and access flexibility reflect how the transport provider can answer to changes in demands for capacity, time and space from the customer and will be further examined below. Naim et al. (2006) highlight that a transport provider should focus on the customer needs, as well as uncertainties connected to demand and their own internal processes. By doing this they can concentrate on achieving flexibility where it leads to customer satisfaction, instead of trying to be flexible in all areas which will be impractical and lead to higher costs.

4.3.1 Access flexibility

When it comes to access flexibility, which is sometimes referred to as flexibility of destination and door-to-door service, road transportation is undoubtedly the best option (Everett and Kittel, 2010). The Swedish Maritime Administration (2016) state that road transport has a flexibility advantage since it is easier to move trucks than vessels or trains to places where they are most needed at the moment. To be able to offer a door-to-door service with SSS, collaboration with road and/or rail transportation is required (Paixão and Marlow, 2002). Ng (2009) highlights that interoperability and smooth transition between transport modes is of great importance for SSS, since most companies are not located right at a port and hence require another mode for the pre- and end-carriage. Without collaboration with other modes for a door-to-door solution, Medda and Trujillo (2010) claim that SSS will not be a real competitive alternative to road transportation. But if SSS is combined with other modes in a proper way that eliminates bottlenecks, Everett and Kittel (2010) argue that SSS can be effective in providing a door-to-door service.

4.3.2 Volume flexibility

The use of vessels requires larger volumes than for example trucks, since vessels have a much higher capacity and the unitary cost will be very high if the load factor of a vessel is low (Morales-Fusco et al., 2013). According to Morales-Fusco et al. (2013), maritime transportation therefore requires a large demand which preferably is constant over time, and sea transportation's strength is the economies of scale and the ability to handle increases in demand. Maritime transport often has a relative advantage against road and rail transport when having large goods volumes or heavy goods (Swedish Maritime Transportation, 2016).

The dimension of the vessel fleet must be adapted to the demand, as it will bring high unit costs to hire extra temporary capacity when the demand is high, and it might be necessary to decrease the frequency when the demand is low (Morales-Fusco et al., 2013). Road transportation on the other hand does not require large volumes (Morales-Fusco et al., 2013) and can according to Baindur and Viegas (2011) easily answer to changing demand dynamics, referring to the trend of smaller but more frequent shipments.

Maritime transportation can however, according to Trujillo et al. (2011), be seen as a flexible alternative when it comes to demand variability, since an increase in volume does not require infrastructural investments in the same way as roads and railways. The railways in Sweden have according to Trafikanalys (2016a) already a very high utilization and an increase in rail freight can make it necessary to expand the railway. Inland Navigation Europe (2014) claim that the waterway is the only mode of transportation with spare capacity. Paixão and Marlow (2002) also highlight the unlimited capacity of the sea, but say that it is of importance to point out that ports can have limited capacity.

4.3.3 Delivery flexibility

Delivery flexibility is described as the range of and ability to change delivery dates (Naim et al., 2006). Maritime transportation usually follows a fixed schedule which gives low or no delivery flexibility and Lagoudis et al. (2010) claim that actors using maritime transportation therefore have very low requirements on delivery flexibility. The ability to change a delivery date is constrained by the speed of the vessel (Lagoudis et al., 2010).

4.4 Frequency

Road transportation provides frequent departures and deliveries, which is important for Just-In-Time strategies that are commonly used today (Paixão and Marlow, 2002). This makes road transportation the benchmark of the industry, while for maritime transportation, frequency is one of the main drawbacks (Trujillo et al., 2011). A vessel takes a much larger volume than a truck, and often larger than a train as well, and the frequency must therefore be lower (Morales-Fusco et al., 2013). The Swedish Maritime Administration (2016) agree and state that shipping has a disadvantage against road and rail transportation since the requirements on lead time and frequency are difficult to match. Ng (2009) claims that in order for SSS to be able to compete with road freight, an acceptable frequency and regularity of service must be offered, even if it cannot be as high as for road transportation.

4.5 Theoretical framework of the logistic performance of coastal shipping

Figure 4.1 illustrates a theoretical framework of the areas presented in this section which affect the logistic performance of coastal shipping.

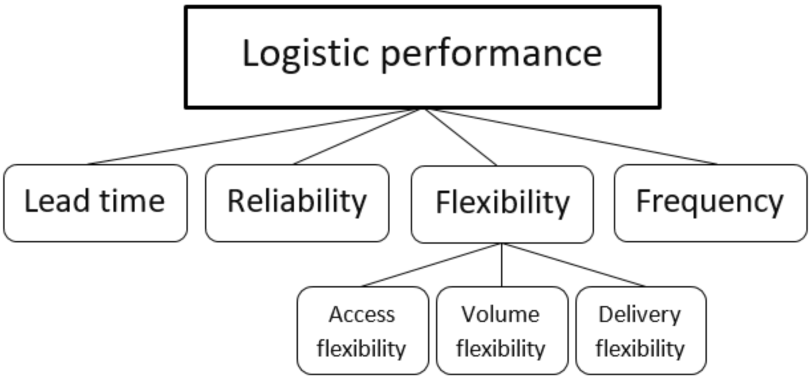

Figure 4.1. A theoretical framework of areas affecting the logistic performance of coastal shipping.

5. Theoretical findings on the environmental performance of coastal shipping

Many authors consider maritime transport to be more environmentally friendly than road transport (Galati et al., 2016; Morales-Fusco et al., 2013; Perakis and Denisis, 2008; Medda and Trujillo, 2010). Medda and Trujillo (2010) also claim that maritime transport is more environmentally friendly than rail transport in Europe, but Kågeson (2011) highlights that the environmental impact from rail transport varies between electrified and non-electrified railways. Perakis and Denisis (2008) argue that since the market is becoming more conscience-focused and the demand for ethical business processes increase, the transportation patterns are likely to change into using more environmentally friendly modes, which according to the authors would benefit maritime transportation. However, López-Navarro (2014) disagrees and claims that the assumption that maritime transport is better for the environment than road transport can be questioned. The results of the study done by López-Navarro (2014) show that road transportation in some cases is preferable from an environmental perspective, and the author therefore concludes that it cannot be assumed that maritime transportation is always more environmentally friendly. López-Navarro (2014) argues that comparative analysis must be made for each specific case in order to evaluate which mode is environmentally preferable. The following section will cover the most common measurements mentioned in literature for assessment of environmental impact from transportation. The section will result in a theoretical framework that is later used in the analysis of the environmental performance of the studied case.

5.1 Energy consumption

Energy consumption is a common measure to use when evaluating environmental impact, since unsustainable energy consumption has negative effects on the global environment (Bilgen, 2014). There exist several different energy sources and the environmental impact differs between the options. The use of fossil fuels leads to emissions of both greenhouse gases and other air pollutants, while nuclear power and renewable energy sources do not cause any greenhouse gas emissions at all (Bilgen, 2014). Maritime transportation is often referred to as the most energy efficient mode of transport, while road transport is the least efficient mode, and rail transport is somewhere in the middle (Kågeson, 2011; Castells Sanabra et al., 2014; Lu and Yan, 2015). Perakis and Denisis (2008) highlight that this is because maritime transportation benefits from economies of scale. A barge that can carry the same load as 60 trucks will not use as much fuel as 60 trucks do altogether, which results in lower energy consumption per tonne-km for a fully loaded barge.

The speed has a large impact on the energy consumption of a vessel, since the concept of slow-steaming (described in section 3.3.2) can be used to reduce fuel consumption (Drewry, 2011). But the relation between speed and energy consumption becomes more inelastic at lower speeds, meaning that even if the speed is reduced by the same degree, the energy consumption will not decrease as much as for a higher speed (Woo and Moon, 2014).

5.2 Emissions

It is not enough to compare energy consumption when evaluating environmental impact, since the level of emissions is dependent on the energy source. Castells Sanabra et al. (2014) claim that air pollution is the weak point for maritime transportation, since the most common propulsion in shipping is dirty fossil fuels. Four substances that are commonly measured are carbon dioxide (CO_2), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and particulate matter (PM) (Madejska, 2013).

It is also of importance to consider where the emissions take place, since some substances produce mainly local impacts while CO_2 has a global effect (Castells Sanabra et al., 2014). Substances with local impacts on human health cause less damage when emitted in unpopulated areas, which gives maritime transportation an advantage since most of the emissions from the vessels are emitted at sea, often far from populated areas (Schrooten et al., 2009). However, both Castell Sanabra et al. (2014) and Schrooten et al. (2009) report that port cities often suffer from pollution of SO_2, NO_x and PM due to the emissions from ships calling at the port. Ports are often located close to densely populated areas, since it is convenient to visit ports that are well-connected and located close to industrial areas (Castells Sanabra et al., 2014). So even if more than 90 % of the emissions are made during the cruising phase at sea, vessels can cause serious air pollution in port cities (Schrooten et al., 2009). The emissions when the vessel lies in port can however be minimized by using electricity from the port instead of running the engines (Kågeson, 2011).

The level of emissions from road transport is dependent on the speed of the truck; the relation can be showed in a U-shaped function, which means that emissions increase at very low and at very high speeds (Medda and Trujillo, 2010). Road congestion is therefore a problem that not only increases the travel time, but also causes higher levels of air emissions, since the speed is reduced on congested roads (Medda and Trujillo, 2010). When using maritime transport instead of road transport, the number of trucks on the roads will decrease which in turn reduces congestion (Morales Fusco et al., 2013).

5.2.1 Carbon dioxide

CO_2 is the most important greenhouse gas that contributes to global warming and climate change (Bilgen, 2014). Sea transport is according to Medda and Trujillo (2010) the transport mode producing the least amount of CO_2 emissions, while road transport produces the largest amount. However, the Royal Academy of Engineering (2013) show that the level of CO_2 emission from shipping is strongly related to the size of the ship; a ship with higher capacity gives lower carbon emissions per goods unit. About 90 % of the Swedish rail network is electrified, including basically all parts that compete with coastal shipping (Kågeson, 2011). When diesel is used, it is only for a small part of the total distance (Kågeson, 2011). The electricity used for trains in Sweden comes from renewable sources, mostly hydropower, which gives close to zero emission of CO_2 (Green Cargo, 2014).

5.2.2 Nitrogen oxides

Emissions of NO_x have a rural impact (Castells Sanabra et al., 2014) and contribute to both acidification and eutrophication of land and water areas, as well as the formation of ground-level ozone (Havsmiljöinstitutet, 2017). IMO have introduced emission standards for NO_x called Tier I-III, where Tier III is the most restrictive and applies to vessels built after 2015, but only in certain areas called NECA (Nitrogen Emission Control Areas) (IMO, 2017a). According to calculations made by Kågeson (2011), the level of NO_x emissions per kWh from vessels in Tier III is equal to the levels emitted by Euro V trucks, while Euro VI trucks reduce the emissions even more. Since 1990, vessel engines have been designed to gradually reduce the emissions of NO_x (Schrooten et al., 2009), but there are no NO_x emission limits for vessels built before 1990 (Castells Sanabra et al., 2014). It can be noted that there is an approximate reduction of 80 % from Tier I to Tier III (IMO, 2017a) and the most common way to reduce the emission of NO_x is by using a selective catalytic reduction (SCR) system (Österman and Magnusson, 2012).

5.2.3 Sulphur oxides

Sulphur oxides (SO_x) are converted to sulfuric acid in the air and contribute to acidification when it reaches ground and sea. Emissions of SO_x to the air are also harmful for human health (Havsmiljöinstitutet, 2017). SO_x therefore have a local impact which makes the population density in the area a critical aspect (Castells Sanabra et al., 2014). Even though sea transport in many aspects is considered the most environmentally friendly mode, sea transport is known to be the mode that emits the largest amounts of SO_x emissions (Martínez de osés and Castells, 2009). Perekis and Denisis (2008) claim that SO_x is the only air pollution substance where shipping performs worse than truck and rail.

The emissions of SO_x are regulated and the allowed levels are different in different areas of the world. Some areas are classified as SECAs, where the permitted levels are lower. The current allowed level of sulphur in the fuel is 3.50 % outside SECAs, and 0.10 % inside a SECA (IMO, 2017b). As a comparison, the allowed level of sulphur in diesel used by trucks is 10 ppm (Kågeson, 2011). The Baltic Sea area and North Sea area surrounding Sweden are established as SECAs.

5.2.4 Particulate matter

Particulate matter (PM) has a local impact where it can cause health problems and its impact is therefore related to the population density in the area (Castells Sanabra et al., 2014). The emission of PM varies between different engines and fuels, and higher sulphur content in the fuel gives higher emissions of PM (Fridell and Salo, 2016). Kågeson (2011) concludes that the emission level for vessels can stretch between 0.2 and 24 g/kWh. This can be compared to the allowed levels for trucks which is 0.02 and 0.01 g/kWh for Euro V and Euro VI, respectively (Kågeson, 2011).

5.3 Theoretical framework of the environmental performance of coastal shipping

The theoretical findings concerning environmental impact of coastal shipping are summarized in Figure 5.1. This theoretical framework will later be used in the analysis of the case study.

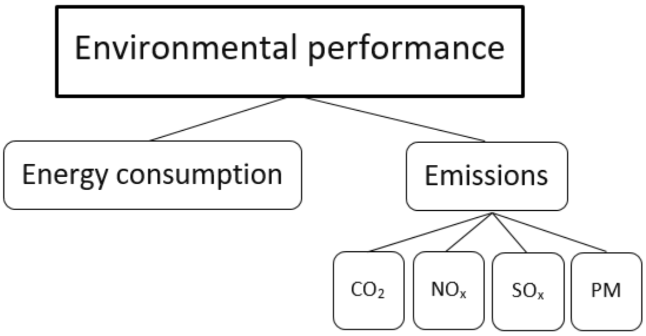

Figure 5.1. A theoretical framework of the areas affecting environmental performance of coastal shipping.

6. Theoretical findings on performance improvements of coastal shipping

According to the Swedish Maritime Administration (2016), there are several areas that can be improved in order to strengthen the competitiveness of coastal shipping. An increased rate of vessel innovation, changes in ports' business models and increased port efficiency are some of these areas. For the Uddevalla-Gothenburg case, the areas hindering the competitiveness of the coastal shipping solution the most are the high loading and unloading costs, and the inappropriate choice of vessel from an environmental perspective (see Chapter 8 and Chapter 10). Therefore, this chapter will present findings from literature regarding performance improvements related to these areas.

6.1 Costs of loading and unloading containers

The Swedish Maritime Administration (2016) claim that port costs have a large impact on the competitiveness of sea transport, especially when the goods volumes are small and the distances are short. Becker et al. (2004) have studied SSS in Europe and conclude that from an economic perspective, the speed of transhipment in ports is far more important to improve than vessel speed, especially on shorter routes. They argue that reduction of time in port has a double effect compared to a similar reduction in transport time, since there is both loading and unloading at each port. Hence, there is a better return of investments in cargo handling than investments in ship propulsion for higher speed (Becker et al., 2004). Konings (2007) is of the same opinion as Becker et al. (2004) and claims that in order to increase the attractiveness of coastal shipping, reductions of handling costs are more efficient than reductions in transport costs. In the following sections, areas affecting the costs of loading and unloading containers will be presented.

6.1.1 Efficiency and layout of port infrastructure

Kasypi et al. (2013) claim that there is a correlation between port efficiency and handling costs. The authors mean that port inefficiency implies higher handling costs but with suitable measures these cost can be lowered. The lack of efficiency in port activities has also been highlighted by Ng (2009) as a major obstacle to SSS competitiveness. Kasypi et al. (2013) state that port costs are possible to reduce if having suitable infrastructure. The Swedish Maritime Administration (2016) claim that in order for coastal shipping and inland waterway transportation to be competitive in Sweden, there must be ports available where goods can be loaded and unloaded in a simple manner. Kasypi et al. (2013), state that the configuration and layout of a container terminal has a strong effect on its productivity and according to Paixão and Marlow (2002), the layout of a port must be carefully planned so that unnecessary waste in port operations can be eliminated (Paixão and Marlow, 2002). Becker et al. (2004) argue that port interfaces should be standardized in order to achieve an efficient and effective SSS network in Europe, since many types of vessels should be able to visit many ports. One way to streamline ports is to use the concept of lean. Marlow and Paixão Casaca (2003) state that by using lean in ports, wastes are eliminated from both physical and information processes which make it possible to move cargo quickly and in alignment with demand. A lean port makes better use of its resources, delivers better customer service and at the same time reduces costs (Marlow and Paixão Casaca, 2003).

One way of measuring efficiency of the loading and unloading activity is to measure the number of moves per hour. According to Ducruet et al. (2014), large port terminals can on average handle between 25-40 moves per hour. The container terminal in Hong Kong is among the most efficient ones in the world and handles on average 36 moves per hour (Marine Department, 2007). However, the number of moves per hour is dependent on the experience of the crane operator. Kasypi et al. (2013) state that crane operators that are inexperienced has a lower and inconsistent productivity than more experienced ones. According to the Swedish Maritime Administration (2016), it could be beneficial for coastal shipping if the handling of container was performed in a simpler way. One suggestion is to have equipment that allows the personnel on board the vessel to handle the loading and unloading activities themselves (Swedish Maritime Administration, 2016). This suggestion is in line with the opinion of Baindur and Viegas (2011) who state that SSS becomes more attractive when using ports that encourage self-handling.

6.1.2 Board-to-board transhipment

Another way to increase the berth productivity is to reduce the number of container moves by moving containers directly from one vessel to another, instead of first unloading them to the quay, and perhaps put the containers in storage, before loading them onto the next vessel. This type of board-to-board transhipment is however a complex process from a logistical point of view (Konings, 2007). Usually, not all containers have the same final destination which implies that there are often several vessels involved in the board-to-board transhipment. This means that direct transhipment requires that the vessels' port calls coincide and some vessels might have to wait in the port for other vessels to arrive. To let vessels wait is not cost-efficient and it becomes even more problematic if there are unplanned delays or changes (Konings, 2007).

6.1.3 Automation

Perakis and Denisis (2008) claim that automation of different port-related activities can reduce the time and costs in ports. Activities mentioned by the authors are: handling activities, the application of information technology applications such as electronic data interchange, and intelligent transportation systems. The Swedish Maritime Administration (2016) state that it is crucial for the competitiveness of coastal shipping that the transhipment activity is cost- and time efficient and according to Saldanha and Gray (2002), costs can be reduced and efficiency can be improved if having automated cargo handling.

6.1.4 Efficient container handling at another port

Barge transport is becoming increasingly used as a transport mode in North-western Europe. Braekers et al. (2013) state that the annual growth rate for barge transport has been as high as

15% during some of the years the past two decades. The Swedish Maritime Administration (2016) state that one possible way to increase coastal shipping in Sweden is to investigate how other countries have done to increase the use of national sea transport. One terminal that has a lot of knowledge about efficient handling of containers transported by barge is Maasvlakte II in Rotterdam, a terminal operated by APM Terminals (APM Terminals, 2017). Maasvlakte II is a highly modern and technologically advanced terminal which was opened in 2015 and considers barges to be among the most important modes of transport (APM Terminals, 2017). From the terminal, goods can be transported by barge to a large part of Europe and APM Terminals (2017) state that the geographic location of the terminal is therefore very good from a strategic point of view. The terminal has a dedicated quay for barges which has cranes that are used only for barge handling. This gives the terminal the opportunity to handle barges in an efficient, quick and reliable way (APM Terminals, 2017). Barges that regularly visit the terminal have fixed time slots for their arrival and departure. According to APM Terminals (2017), this enables a quick and reliable handling of the containers which is beneficial both for the terminal and the barge operator. What further facilitates the handling of containers is that every barge must send an electronic pre-notification before arrival that describes the barge and the cargo (APM Terminals, 2017). The pre-notification allows the terminal to plan the unloading of containers and where the containers will be transported next. Moreover, APM terminals (2017) describe that Maasvlakte II has created standards and instructions for how the handling of barges should be performed in order to streamline the handling activities even more. Many of the handling activities at the terminal are fully automated, such as the transportation of containers to and from the stack which is handled by battery driven Lift AGVs (Automated Guided Vehicles). At Maasvlakte II, automation is considered to be a great contributor to port efficiency, high productivity and predictability of handling activities (APM Terminals, 2017). The loading and unloading of containers onto and off the barges are, however, handled manually due to safety reasons.

6.1.5 Price structure

Swedish Maritime Administration (2016) suggests that in order to improve the economic performance of SSS, ports should reconsider their price structures. Baindur and Viegas (2011) claim that there are large varieties in price structures between European ports, and it is often unclear what ports base their charges on. By changing the price structures, coastal shipping can become more competitive, but as previously mentioned, price structures are often influenced by a port’s geographical monopoly and by the high costs of equipment, facilities and port personnel (Swedish Maritime Administration, 2016).

6.2 Choice of vessel for improving environmental performance

The analysis in Chapter 10 will show that the environmental requirements cannot be fulfilled with the prerequisites of the studied theoretical case. The barge pusher used for calculations has high fuel consumption and is built in 1980 which results in high emission levels. It is therefore of interest to investigate if the environmental results for coastal shipping can be different if using another vessel. This section presents theoretical findings regarding the environmental performance of vessels and how it can be improved.

6.2.1 The importance of vessel choice

Even if maritime transportation is considered an energy efficient mode (Perakis and Denisis, 2008), the energy consumption per tonne-km is dependent on the load factor, the design of the vessel and the technology used. Both the Swedish Maritime Administration (2016) and Braekers et al. (2013) argue that vessel capacity is one of the most important design decisions and that it must be optimized and adapted to the volumes. The fuel consumption and cost for running a larger vessel is only marginally higher than a smaller vessel, which results in a lower fuel consumption and cost per tonne-km for the larger vessel, given that the load factor is the same (Swedish Maritime Administration, 2016). Even if maritime transport in general is an energy efficient mode when taking advantage of the economies of scale, the requirements regarding emissions for maritime transport has so far been quite low compared to the requirement for trucks (Swedish Maritime Administration, 2016). Stricter limits for SO_x have however been implemented recently, and Elgohary et al. (2015) believe that the pressure for more extensive and severe limits for SO_x, NO_x and PM will increase.

According to Konings (2007), the best choice of vessel for a feeder flow is a push boat-push barge solution. In contrast to other vessels, the cheap barge can be uncoupled from the push boat and left waiting in a port as a stack unit, while the more expensive push boat can continue with another barge that is ready to leave the port (Konings, 2007). As previously mentioned, it can be inefficient from a cost perspective to let a vessel wait in port and a push boat-push barge solution is therefore more cost efficient (Konings, 2007). The use of new technologies in the marine industry has generally been limited, the actors are careful with adopting new technologies due to the extremely large investments often required (Royal Academy of Engineering, 2013). Vessels also have a long lifespan, which makes the development and adoption of new technologies slower than for example the development of trucks (Swedish Maritime Administration, 2016). The finance of shipping companies is continuously influenced by the world trading and political scenarios worldwide. Adoption of new technologies must therefore always be evaluated from a global perspective (Royal Academy of Engineering, 2013).

6.2.2 Diesel vessels

The Royal Academy of Engineering (2013) state that for an average tanker or bulk carrier without energy saving measures, only 27 % of the total energy input goes to the actual propulsion of the vessel. The rest of the energy is mainly taken away as waste heat. But there are a number of energy efficiency technologies that can be applied to increase the efficiency and thereby minimise the fuel consumption (Royal Academy of Engineering, 2013). Ljungqvist et al. (2017) studied a case where containers were transported by barge and several parameters were measured, including fuel consumption. The fuel consumption for a vessel with the capacity of 96 TEUs was estimated to 90 litres per hour (Ljungqvist et al., 2017). By reducing the fuel consumption, both the emission levels and energy consumption can be reduced, but emissions can also be reduced with other measures. Selective catalytic reduction (SCR) systems are currently the most effective way to reduce the NO_x emissions from a diesel engine (Wik and Niemi, 2016). The Royal Academy of Engineering (2013) claims that the emissions can be reduced by 80 % with the use of SCR. Wik and Niemi (2016) believe that the reduction can be even better, up to 95 %, but state that cost and layout constraints make it difficult to reach this in reality and that 80-85 % reduction is more realistic.

Emissions of sulphur oxides (SO_x) are as already mentioned one of the drawbacks of sea transport, but the emissions of SO_x have been reduced a great deal due to the introduction of SECA (IMO, 2017b). There are basically two different ways of reducing the SO_x emissions to the levels required in SECAs. One is to use a fuel with low sulphur content, like MDO (Marine Diesel Oil), instead of HFO (Heavy Fuel Oil). Another alternative is to use a gas cleaning system called a scrubber, which reduces the SO_x content in the exhaust gas (Fridell and Salo, 2016). A scrubber can be installed to an already existing vessel (Peckham, 2011) and for vessels that spend a lot of time in SECA areas, it can be economically preferable to install a scrubber instead of using the more expensive low sulphur fuels (Fridell and Salo, 2016). A scrubber can according to a study made by Fridell and Salo (2016), reduce the SO_x emissions by 99 % when using HFO, which results in lower SO_x emissions than when changing fuel to MDO.

The level of PM emissions is strongly connected to the sulphur content in the fuel and a change from HFO to a low sulphur fuel gives a reduction in PM emissions of approximately 75 % (Fridell and Salo, 2016). Fridell and Salo (2016) have in their study also measured the reduction of PM emissions from using a scrubber together with HFO, which shows that the total PM emissions are reduced by 75 %, equal to a fuel switch to a fuel with low sulphur content. Elgohary et al. (2015) mention that PM emissions can also be reduced by using electrostatic filters. The author claims that the emissions of PM can be reduced by up to 85 % with the use of electrostatic filters.

6.2.3 Alternative energy sources

Diesel engines are the dominant mechanism for marine propulsion (Royal Academy of Engineering, 2013). But there exists other alternatives, some of them available already and some that are expected to be a future solution for propulsion. Three of the most commonly mentioned alternatives in literature are Liquefied Natural Gas (LNG), methanol and electricity.

LNG is natural gas that has been cooled down to -162 °C where it becomes liquid (Elgohary et al., 2015). LNG gives significant improvements in terms of emissions where NO_x emissions are reduced by 85 % and SO_x emissions are eliminated completely since there is no sulphur in the fuel (Royal Academy of Engineering, 2013). Furthermore, the emissions of PM can be decreased by 96 % (Elgohary et al., 2015). The benefit in terms of CO_2 emissions is however smaller. The Royal Academy of Engineering (2013) claims that CO_2 is reduced by 25 %, while Elgohary et al. (2015) say that it is reduced by only 11 %. There exist vessels today that use LNG for propulsion, but the infrastructure for bunkering is inadequate (Royal Academy of Engineering, 2013). Wik and Niemi (2016) conclude that the infrastructure and availability in ports is the main question that needs to be addressed. Even if there are challenges regarding greenhouse gases and infrastructure, Wik and Niemi (2016) consider LNG to be the fuel of the future. Elgohary et al. (2015) are of the same opinion and claim that a change to LNG will also result in economic savings due to a lower fuel price.

Methanol has been tested as a fuel for trucks and is according to Andersson and Márquez Salazar (2015) an alternative for marine transport as well. Methanol is sulphur-free just like LNG and the NO_x emissions are 2-4 g/kWh, which is in line with NO_x Tier III (Andersson and Márquez Salazar, 2015). The emissions of PM can be reduced by up to 95 % compared to when using HFO. Methanol can be produced in different ways, and the production stage has a large impact on the total emission of CO_2 (Brynolf et al., 2014). Methanol can be produced from 100 % renewable sources and would then meet even the strictest CO_2 emission regulations in the future, but when produced from for example natural gas, the CO_2 emissions are approximately at the same level as for HFO (Brynolf et al., 2014). In Sweden, renewable methanol is produced from black liquor, which is a by-product from pulp and paper mill (Andersson and Márquez Salazar, 2015).

There are not yet any larger vessels using full battery propulsion. The size of the needed battery would be too large and the Royal Academy of Engineering (2013) state that an energy storage breakthrough is needed if it is to be used as main propulsion. They argue that battery-based propulsion could be a future solution for smaller ships, but also a potential hybrid solution together with other modes of propulsion. The Swedish Maritime Administration (2016) argue that battery propulsion is a potential alternative for vessels that carry passengers, but do not mention the potential regarding shipping of goods.

7. Performance requirements for the coastal shipping solution between Uddevalla and Gothenburg

In this section, the first research question is analysed and a list of requirements for a competitive coastal shipping solution between Port of Uddevalla and Port of Gothenburg is created. The section starts with a comparison of interviewees' opinions regarding different economic, logistic and environmental aspects of the potential coastal shipping solution. Thereafter, the interviewees' opinions are compared with theory about requirements for a competitive coastal shipping solution, and lastly a list of requirements is presented.

7.1 Interview data comparison

In Table 7.1, some interviewees' opinions are compared regarding economic, logistic and environmental aspects of the coastal shipping solution between Port of Uddevalla and Port of Gothenburg. The interviewees included in the table are those who have the most knowledge about the actual flow of goods between Port of Uddevalla and Port of Gothenburg and who are most familiar with potential customers' requirements for a successful coastal shipping solution. Information gathered from other interviewees is also of importance when creating the list of requirements. However, these interviewees have more knowledge about shipping in general and are not as involved in the actual case that is studied in this report. The performance factors included in the table are factors that were found in theory about the performance of coastal shipping, and which were also raised during interviews as important for the coastal shipping solution studied in this case.

Table 7.1. Comparison of interviewees' opinions regarding economic, logistic and environmental aspects of the coastal shipping solution between Port of Uddevalla and Port of Gothenburg.

	Interviewee 1	Interviewee 2	Interviewee 3
Economic			
Total cost	Cannot be higher than today's solution.	Cannot be higher than today's solution.	Must be lower than today's solution.
Logistics			
Transportation time	Short transport time is not as important as on-time reliability.	–	Short transport time is not as important as on-time reliability.
Reliability	Reliability is extremely important. Customers do not care about transport mode as long as the on-time reliability is high. Arrival and departure cannot deviate more than a few hours from appointed time.	Reliability is important.	Reliability is very important. Some customers are willing to pay more for higher on-time reliability.
Frequency	At least two departures per week, prefarably more.	At least two departures per week.	At least one departure per week, but that requires high reliability.
Volume flexibility	Volume flexibility is required. The number of containers per week vary considerably.	–	–
Environment			
Customer prioritization	Only one of the customers are willing to pay extra for an environmentally friendly transport solution.	Customers do not take environmental apsects into consideration.	Customers do not pay extra for an environmentally friendly transport solution. Environmental aspect can be considered if the price for two solutions is the same.
Company engagement	Port of Uddevalla has an internal environment program where emissions are measured.	–	CMA CGM is largely engaged in devloping environmentally friendly transport solutions.

7.2 Economic requirements

The interviewees' opinions regarding economic performance are further analysed in this section. First, a theoretical framework of areas affecting economic performance in coastal shipping is presented. Thereafter it is analysed whether or not these areas are important for the studied case in creating a list of requirements for a competitive coastal shipping solution.

As presented in Figure 7.1, port costs, transport costs and external costs are the main costs that affect the economic performance of coastal shipping. When interviewing people involved in the Uddevalla-Gothenburg case, all interviewees stated that it is the total cost that is most important and no one distinguished between port costs, transport costs and external costs when requirements for a competitive coastal shipping solution was discussed. If for example the transport costs would be low but the port costs would be high, the total cost would still be the deciding measure on whether the solution is attractive for customers or not. Hence, the performance measure further analysed in this section is total cost.

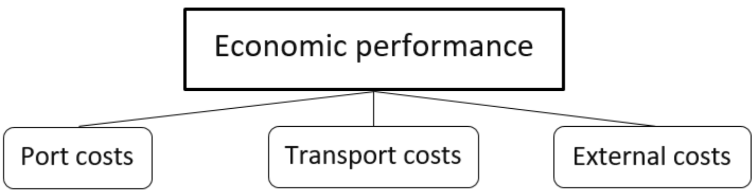

Figure 7.1. A theoretical framework of areas affecting economic performance of coastal shipping.

7.2.1 Total cost

All interviewees clearly stated that the economic performance of the transport solution is of great importance. The costs can be derived from different parts of the transportation chain and from different activities, but the only measure that the interviewees name as important is the total cost. This is in line with the findings of earlier research, concluding that total cost is one of the most crucial factors when selecting transport mode (Yang et al., 2014; Everett and Kittel, 2010; Swedish Maritime Administration, 2016). As can be seen in Table 7.1, two of the interviewees believe that if the coastal shipping arrangement should have a chance to become an attractive permanent solution, the total cost cannot be higher than it is for today's solutions with road and rail transport. The third interviewee on the other hand, does not consider it enough to reach the same total cost level as the current solutions. He believes that the total cost must be even lower for the coastal shipping arrangement to become an attractive transport solution for customers. His statement hence strengthens the view of Baindur and Viegas (2011) and Paixão and Marlow (2002) that the customer is only willing to switch from road to maritime transportation if the total cost is considerably lower. Baindur and Viegas (2011) claim that the cost must be at least 30 % lower, and Paixão and Marlow (2002) claim that it must be 35 % lower. Another interviewee, not included in Table 7.1, is also of the opinion that the cost for coastal shipping must be lower, but that the difference not necessarily must be as large as 30 %. According to him, switching to shipping brings some inconveniences related to long lead time and higher risk that a customer is willing to accept only if the total cost is lower. Hence, it can be concluded that the coastal shipping solution must reach the same or a lower price level than the currently used road and rail transport in order to be an attractive solution to customers.

7.3 Logistics requirements

In this section, the interviewees' opinions regarding important areas of logistic performance are analysed. A theoretical framework of areas affecting logistic performance in coastal shipping is presented and compared with interviewees' opinions about these areas. As presented in Figure 7.2, theory mentions four main areas that affect the logistic performance of coastal shipping. All four areas were also mentioned during the interviews and each area will therefore be further analysed.

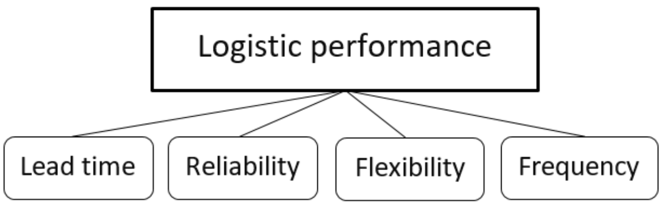

Figure 7.2. A theoretical framework of areas affecting logistic performance of coastal shipping

7.3.1 Lead time

The trend in shipping has during the last ten years been to decrease fuel costs by going at a rather slow speed, which means a longer transportation time (Notteboom and Cariou, 2013). This indicates that a short lead time, in this case defined as the time from starting the loading of containers onto the vessel until all containers have been unloaded in the other port, is not as important as the total cost. This is in line with the results from the interviews, where two of the interviewees insist that short lead time is not of importance. However, it is important that the time for transportation and handling can be predicted, because this affects the reliability.

The choice of speed in shipping causes a trade off since higher speed leads to higher fuel consumption, while slower speed leads to a longer transportation time and additional inventory costs due to tied up capital (Notteboom and Cariou, 2013). It was clear from the interviews that the goods shipped in containers between Port of Uddevalla and Port of Gothenburg today can be categorized as low value goods and the additional inventory cost caused by longer lead time is therefore limited. This strengthens the statement that a short lead time is not prioritized in the case of this study, which is also in line with the opinion of Perakis and Denisis (2008) that a short lead time is not a priority when using SSS. It is however important to remember that the inventory carrying costs are associated with the characteristics of the goods, which implies that if the type of goods is changed or broadened in the future, the lead time could have a greater influence on total costs.

In addition to fuel cost and inventory carrying cost, transportation time also has an immediate effect on personnel costs, since a longer transportation time means more work hours. All of these effects must be considered when deciding the speed of a vessel. The same reasoning applies to administration time and handling time in port. It is not a requirement to reach a short administration or handling time, but these activities affect the total cost. Since a short lead time between Uddevalla and Gothenburg is not a goal in itself, it is rather a question of finding the optimal speed, administration routines and handling routines that minimize total cost. Hence, the outcome of this analysis is that there are no certain requirements for lead time when it comes to creating a competitive coastal shipping solution between Uddevalla and Gothenburg.

7.3.2 Reliability

Reliability is highlighted by all the interviewees as one of the most important performance indicators, which coincides with the results of the literature study. Perakis and Denisis (2008) and Md Arof (2015) argue that it can often be seen as the most important requirement. One of the interviewees confirms this statement by saying that some customers are willing to pay more for a higher on-time reliability, which shows that it is sometimes even more important than total cost. The interviewee explains that customers that buy for example raw material or parts plan their production based on the shipper's arrival plan. If the goods do not arrive on time there is a risk that the production runs out of material, which will cause huge extra costs. If the containers from Port of Uddevalla arrive late to Port of Gothenburg, the containers may miss the departure of the larger container vessel going out from Port of Gothenburg. The interviewee explains that the containers will then have to be stored in the port until the next departure for the same destination, which might take a week or more. So even if the containers arrive only one day late to Port of Gothenburg, the consequence can be a much longer delay for the final destination and additional costs for storage in the port area. Another interviewee is also of the opinion that a delay of one day is not acceptable. He believes that the arrival time must be within a time frame of a few hours to be considered reliable, and to avoid extra costs for loading and unloading on overtime.

It can hence be concluded that high reliability is a very important requirement for the coastal shipping solution between Uddevalla and Gothenburg. The customers are not likely to accept lower on-time reliability than that of the current transportation solutions, which is consistent with the statement made by the Swedish Maritime Administration (2016) that customers want the same service and reliable deliveries that they have in their current transport arrangements. The performance requirement regarding reliability is therefore that departure and arrival cannot deviate more than a few hours from appointed time.

7.3.3 Flexibility

As Naim et al. (2006) argue, there are many different aspects of flexibility in transportation and it is important for the transport provider to focus on the areas that are actually needed and adds value for the customer. Product and mix flexibility refer to the nature of the transport service (Naim et al., 2006), for example the ability to change to a different mode of transport. Product and mix flexibility have not been identified as requirements in this study, since the case only includes coastal shipping on a specific route.

The average volume that is transported from Port of Uddevalla to Port of Gothenburg is 42 forty-foot containers per week, but one interviewee explains that the volumes can vary a great deal between weeks. As an example, he mentions that there can be 45 containers one week and only ten containers the week after. These variations arise from the customers' sales patterns. Even if the volumes are assumed to increase, rather high volume flexibility is required for the coastal shipping solution. For the existing road and rail solutions the interviewee states that there is a fixed cost per container, irrespective of the number of containers transported that week, which gives high volume flexibility. The customers' sales patterns, together with the high volume flexibility of the current solutions, leads to the requirement that the transport solution must be able to handle variations in volume.

Access flexibility, or flexibility of destination, is mentioned in previous studies as a common requirement for goods transportation (Medda and Trujillo, 2010). Customers usually want to buy a door-to-door service, which can create a complex situation for maritime transportation. However, in this study, only the route between Port of Uddevalla and Port of Gothenburg is considered which means that access flexibility is not a requirement.

Another type of flexibility is delivery flexibility, referring to the ability to change the time of arrival at the destination (Naim et al., 2006). None of the interviewees mention delivery flexibility as a requirement in this case. Instead, one of the interviewees argues that it would be an advantage to have the same departure and arrival schedule every week. In his opinion, increased delivery flexibility could lead to an increased risk related to on-time reliability. Since on-time reliability is one of the most important requirements for this case, this uncertainty is not desirable and delivery flexibility is therefore not rated as a requirement.

7.3.4 Frequency

According to Ng (2009), the frequency of departures in a SSS solution is crucial for its competitiveness against road and rail transport. Trujillo et al. (2011) claim that one of the main drawbacks of SSS, relative to the other transport modes, is the lower frequency and Ng (2009) states that an acceptable frequency is required for a SSS solution to be competitive. The interviewees agree regarding the importance of frequency and two of them claim that there must be at least two departures per week in order for the transport solution to be attractive for customers. One interviewee explains that if there would be only one departure per week, alternative transport solutions with road and rail would have to be used as well. He also highlights the importance of having enough goods to ship so that it is possible to have a high load factor on two or more vessels per week. Otherwise, he thinks the solution will not be competitive. Two departures per week would, according to one of the interviewees, be possible to schedule so that personnel in ports can handle the vessel during regular work hours and costs for overtime can be avoided. If there would be more than two departures, the interviewee thinks it could be problematic to handle loading and unloading within regular work hours.

According to another interviewee, the minimum frequency could be one departure per week but in this case the solution would be quite sensitive to disturbances. If the departure would be cancelled one week due to some circumstances, the customers would have to wait a whole week until the next departure. According to the interviewee, this is not acceptable by customers since it could prolong the total lead time for their products substantially. He further claims that if the frequency would be one departure per week, the price against customers for the coastal shipping solution would have to be much lower than for road and rail transport due to the large risks it implies.

A third interviewee also considers high frequency to be important and in order for coastal shipping to be competitive in general, he thinks five departures per week are necessary. However, he also mentions that it is difficult for coastal shipping solutions to match this high frequency. The interviewee's opinions are similar to the ones by Paixão and Marlow (2002) who claim that frequent departures are important for time-based logistics such as Just-In-Time strategies. In the studied case, however, Just-In-Time strategies have not been mentioned during interviews and a frequency of five departures per week is not necessary. The high risk that only one departure per week would induce can be considered as too high for this case, especially since the reliability is very important. It can therefore be concluded that a frequency of at least two departures per week would be required for the customers to accept a coastal shipping solution.

7.4 Environmental requirements

This section compares interviewees' opinions regarding environmental requirements for a competitive coastal shipping solution with areas that theory says affect environmental performance of coastal shipping.

Theory mentions two main areas that affect the environmental performance of coastal shipping: energy consumption and emissions. However, not much consideration was taken to different environmental aspects when discussing the potential coastal shipping solution during interviews. When environmental aspects were asked about, the interviewees did not distinguished between the areas presented in Figure 7.3 and therefore, environmental requirements will be analysed without any categorization into smaller areas.

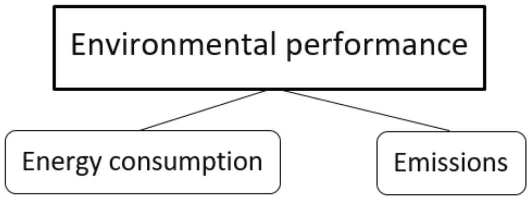

Figure 7.3. A theoretical framework of areas affecting logistic performance of coastal shipping

7.4.1 Environmental impact

It is widely mentioned in theory that SSS is an environmentally friendly mode of transportation (Galati et al., 2016; Morales-Fusco et al., 2013; Perakis and Denisis, 2008; Medda and Trujillo, 2010). Furthermore, Perakis and Denisis (2008) claim that companies are increasingly willing to use more environmentally friendly modes since they are becoming more conscience-focused and care about having ethical businesses. The interviewees did not completely agree with Perakis and Denisis (2008). Instead they all said that most customers do not consider environmental aspects to be very important. It is uncommon that customers are willing to pay more for an environmentally friendly transport solution. One interviewee mentions that only one of his customers today is willing to pay more for using the environmentally friendlier option of rail transport instead of the cheaper option of road transport. The underlying reason for this willingness to pay extra is according to him that the customer company has another transport solution in another part of the world that is quite harmful for the environment. Thus, the customer uses rail transport in Sweden to compensate for the negative environmental impact elsewhere and by that be able to perform better in environmental goals set by the company. According to another interviewee, customers never consider environmental aspects when choosing a transport mode and he does not think they will start doing it in the near future either. Yet another interviewee thinks, on the other hand, that customers may opt for the more environmentally friendly option as long as the available options are similar in price. However, this interviewee has never had a customer who prioritize environment over price and therefore, price seems to be of much higher priority for the coastal shipping solution than environmental aspects.

Even though customers seem to be quite uninterested in using more environmentally friendly modes of transport, it was clear during the interviews that both Port of Uddevalla and the shipping company CMA CGM are interested in developing more environmentally friendly solutions. Both companies have internal environment programs where their impact on the environment is measured. Also Port of Gothenburg has a strong environmental focus which they show by for instance giving a discount on their port charge to vessels that meet certain environmental standards (Port of Gothenburg, 2016). Even though customers are unwilling to pay extra for an environmentally friendly solution, the interviewees agree on that the coastal shipping solution will not have an advantage against road and rail unless it is more environmentally friendly than these modes. It must be possible to use the environmentally friendliness as a sales argument when trying to get customers to use the new transport solution, otherwise the interviewees believe that customers will not bother to switch to the new transport solution. Even if the coastal shipping solution could be offered at a lower price than road and rail transports, customers could, according to one of the interviewees, be unwilling to change to a new transport mode due to the convenience in doing “business as usual”. However, if the coastal shipping solution also could offer a better environmental performance than the other modes, this could be a good sales argument.

During the interviews, no certain environmental requirements for e.g. emissions were mentioned but there are some rules and regulations that are necessary to comply with in order for the coastal shipping solution to be feasible. The route between Port of Uddevalla and Port of Gothenburg is within a SECA which means that there are certain requirements on using low level sulphur fuels (IMO, 2017b). There might also be future regulations regarding emissions of nitrogen oxide, but since these regulations will only affect newly built vessels, the coastal shipping solution in this case will not be affected in the near future. It can then be concluded that apart from complying with environment-related regulations, there are no certain requirements for environmental measures. But in order for the solution to be possible to promote, it must be more environmentally friendly than road and rail transport.

7.5 List of requirements for a competitive coastal shipping solution

The analysis in this chapter has identified the level of performance that would be required to make coastal shipping a competitive option for container transportation between Port of Uddevalla and Port of Gothenburg. Table 7.2 summarizes the performance requirements that must be fulfilled, and will serve as a foundation for the continuation of the analysis.

Table 7.2. Performance requirements for a competitive coastal shipping solution between Port of Uddevalla and Port of Gothenburg.

Performance requirements for a competitive coastal shipping solution between Port of Uddevalla and Port of Gothenburg	
Economic performance	
Total cost	Same or lower price as today’s rail and road transport solutions
Logistic performance	
Reliability	Departure and arrival cannot deviate more than a few hours from appointed time.

Frequency	At least two departures per week from each port
Volume flexibility	The transport solution must be able to handle variations in volume
Environmental performance	
Environmental impact	The transport solution must be more environmentally friendly than road and rail transport

8. Fulfilment of the economic performance requirement

The economic performance requirement for a competitive coastal shipping solution between Port of Uddevalla and Port of Gothenburg is to have the same or a lower price than today's road and rail transport solutions. To evaluate if the coastal shipping solution can reach this price level, the total cost of coastal shipping has been calculated and compared to the cost of road and rail transport. The calculations have been made using the economic performance calculation model which was developed for this study (see section 2.5.4 and Appendix B).

According to the theoretical framework, there are many different cost items affecting the total cost of sea transport (see Figure 8.1). All of these cost items have been considered when calculating the total cost of the coastal shipping solution and each cost item and its contribution to the total cost will be further explained in this chapter. Prices paid today by the Port of Uddevalla for road and rail transport have been used to compare the total economic performance of the different transport solutions.

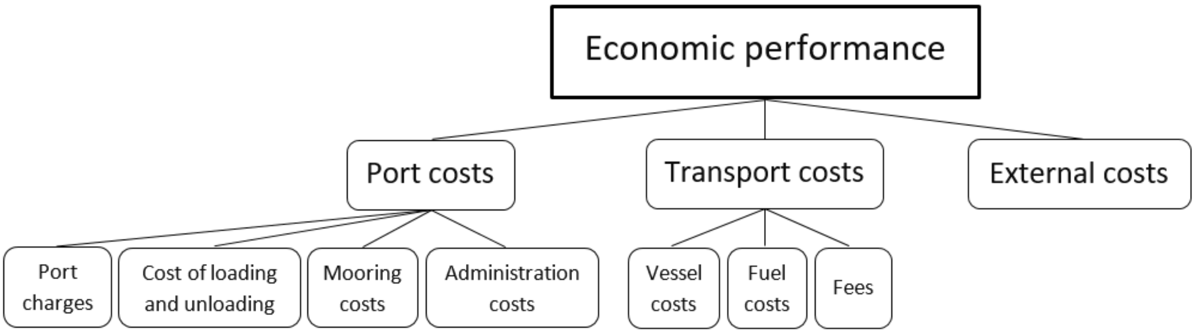

Figure 8.1. Cost items affecting the economic performance of sea transport.

When calculating costs, an assumption has been made that the load factor of the vessel is 80 %, meaning 45 FEUs and 11 TEUs per trip. Today, there is only on average 42 FEUs transported between Port of Uddevalla and Port of Gothenburg per week, but according to one of the interviewees, the volume should be relatively easy to increase in the future.

8.1 Port costs

All costs incurred once the vessel has reached the port have been categorized as port costs. For the coastal shipping between Port of Uddevalla and Port of Gothenburg, port costs make up 53 % of the total costs (see Figure 8.2). According to Paixão and Marlow (2002), port costs can sometimes make up as much as 70-80 % of the total costs of short distance shipping. Even though the port costs in the Uddevalla-Gothenburg case do not reach such a high share of the total costs, they still make up the majority of the costs. The Uddevalla-Gothenburg case falls into the interval found by the Swedish Maritime Administration (2016) of 36-62 % port costs, but it does not reach such a high share as 62 %, as the case with the comparable distance of 100 km studied by the Swedish Maritime Administration (2016) does.

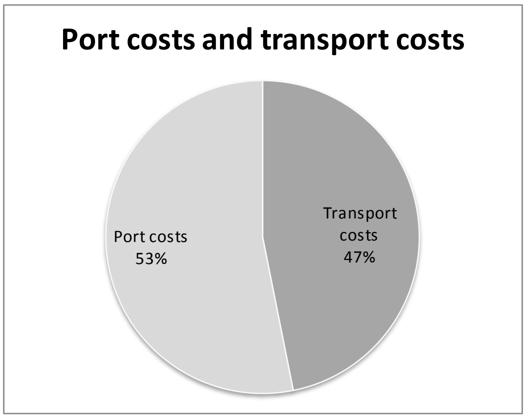

Figure 8.2. The relative share of port costs and transport costs in the coastal shipping solution between Port of Uddevalla and Port of Gothenburg.

The cost items included in the port costs are presented in Figure 8.3 and will be further discussed in this section.

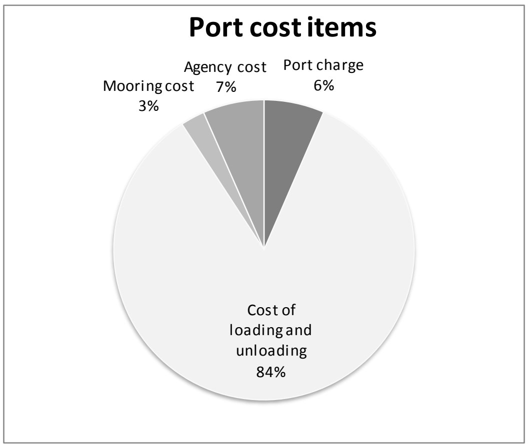

Figure 8.3. Cost items included in the port costs.

8.1.1 Port charges

The port charge to be paid when calling at a port varies considerably depending on the port's cost structure. The Port of Uddevalla base their port charge on the type of vessel, the vessel's gross tonnage and the NO_x emission levels of the vessel (Uddevalla Hamnterminal, 2017). Higher port charges are charged for heavier vessels and vessels with high NO_x emission levels. Port of Gothenburg also base their port charge on the type of vessel and the vessel's gross tonnage (Port of Gothenburg, 2016). However, the emission-related discount is calculated differently compared to the Port of Uddevalla. A 10 % discount is given to vessels that reach an Environmental Ship Index score of 30 points or are classified as "green" by Clean Shipping Index, and a 20 % discount is given to vessels that use LNG as their fuel (Port of Gothenburg, 2016). According to one interviewee, the income from port charges is used for maintenance of the port and the port charge is negotiable if a vessel is frequently calling at the port.

When calculating the total port charges from Uddevalla and Gothenburg, these make up 6 % of the total port costs of the coastal shipping solution which is a very small share of the total costs. The barge pusher that is proposed to be used for the coastal shipping solution does not qualify for any port charge discounts, which means that both ports decide the port charges based on the same parameters: vessel type and gross tonnage. However, the port charge in Gothenburg is approximately 40 % lower than the charge in Uddevalla (Port of Gothenburg, 2016; Uddevalla Hamnterminal, 2017). Even though both Port of Uddevalla and Port of Gothenburg clearly state that the port charges are based on vessel type, gross tonnage and environmental considerations, the ports do not state what the prices charged per gross tonnage are based on. This is in line with the claim of Baindur and Vegas (2011) who state that underlying cost structures for port charges are often not transparent. However, since the Swedish Maritime Administration (2016) argue that port charges are often influenced by a port's geographical monopoly, equipment costs, personnel costs, collective labour agreements and the cost of facilities, this is probably also the case for Port of Gothenburg and Port of Uddevalla.

The port charge is a cost that yields a competitive disadvantage for coastal shipping since, according to Baindur and Viegas (2011), there is no charge for road and rail transport which corresponds to the port charge. One of the interviewees confirms this claim and states that no similar charge is paid for road or rail transport between Port of Uddevalla and Port of Gothenburg today. Since infrastructural costs for road and rail are higher than the investment and maintenance costs for ports (Paixão and Marlow, 2002), it would be beneficial for the competitiveness of coastal shipping if road and rail transport would be subject to charges similar to the port charge.

8.1.2 Cost of loading and unloading containers

Costs of loading and unloading containers are often very high and make up a large share of the total costs for coastal shipping (Lu and Yan, 2015). This is true also in the studied case where the cost of loading and unloading makes up 84 % of the total port costs and is the absolute largest share of the total costs for the coastal shipping solution. Factors affecting the cost of loading and unloading containers are the time it takes to lift containers onto/off the vessel, the personnel cost and the cost of the crane (Swedish Maritime Administration, 2016). These factors differ between Port of Uddevalla and Port of Gothenburg, which also makes the costs of the loading and unloading activities differ between the ports.

Many authors agree on that high handling costs in ports is a disadvantage for the competitiveness of coastal shipping and it is important to reduce these costs (Swedish Maritime Administration, 2016; Baindur and Viegas, 2011; Lu and Yan, 2015). One interviewee claims that the best way to reduce the costs of the loading and unloading activities is to decrease the time it takes to lift one container onto/off the vessel, i.e. increase the moves per hour. The calculations made for costs of loading and unloading containers in Port of Uddevalla are based on ten moves per hour. However, one interviewee estimates that it is possible to make 12-15 moves per hour in the Port of Uddevalla, but since the personnel has little experience in lifting containers, and no experience in lifting containers onto/off a barge, this number can probably be increased even more with practise. As Johnson and Styhre (2015) mention, the efficiency in handling can be increased if having frequent calls at a port. The handling costs in Port of Uddevalla are therefore likely to decrease as the stevedores get more acquainted with how to load and unload the barge. In Port of Gothenburg, one interviewee estimates that 18 moves per hour are possible today and at this port the personnel have a great deal of experience in loading and unloading containers. The moves per hour are therefore not expected to increase as much in this port as in the Port of Uddevalla when having frequent calls at the port.

The Swedish Maritime Administration (2016) state that the high costs of handling containers in ports is largely dependent on high personnel costs. It was discovered through the interviews that three persons are involved in the loading and unloading of containers in the Port of Uddevalla, while Port of Gothenburg use eight persons. Just as the Swedish Maritime Administration (2016) claim, the personnel costs in Port of Uddevalla and Port of Gothenburg are, according to the interviewees, difficult to change due to collective labour agreements, but in the Port of Uddevalla, depreciation and maintenance of the crane is actually a higher cost than personnel cost during the loading and unloading activity. Paixão and Marlow (2002) mention that the efficiency in handling will be low if using equipment that is not suitable for the type of goods handled, or if using the equipment incorrectly. Both Port of Uddevalla and Port of Gothenburg use equipment that is suitable for containers and there should not be any efficiency losses due to incorrect handling. The efficiency could be increased if using faster cranes and by that increasing the moves per hour. However, it is stated by one of the interviewees that it is not economically viable to invest in new equipment only for the new coastal shipping solution.

The cost of loading and unloading containers differs between Port of Gothenburg and Port of Uddevalla and the reason why is probably because there are differences in the number of people involved, equipment used and price structures for the lifting activity. One of the interviewees explains that the exact prices charged for the loading and unloading activities in Port of Gothenburg are different from case to case and are agreed upon in contracts between the port and shipping companies. Another interviewee states that this is a common phenomenon in ports. Prices charged for loading and unloading are dependent on the market and are in most cases decided after negotiation between the port and the shipping company.

The corresponding loading and unloading cost for trucks and trains is lower than for vessels. Several of the interviewees are of the same opinion and claim that the lower cost is due to the much cheaper equipment used for loading trucks and trains. The investment cost of a crane used for loading vessels is, according to one of the interviewees, considerably higher than the investment cost of a reach stacker used for loading trucks and trains. Moreover, the interviewee explains that a reach stacker is possible to utilize more than a crane which lowers the loading and unloading cost per container for a truck or a train. This reasoning is in line with the Swedish Maritime Administration (2016) who claim that the acquisition cost of container handling equipment in ports is very high and to economically justify this large investment, a high utilization and a large scale is necessary.

8.1.3 Mooring costs

When a vessel reaches a port, it must be fastened and secured at the berth. At Port of Uddevalla and Port of Gothenburg, stevedores help the crew on board to moor the vessel and one interviewee explains that this service implies a mooring cost. Out of the total port costs, the mooring cost is a small part, only 3 %. If the coastal shipping between Port of Uddevalla and Port of Gothenburg would become a permanent solution, the mooring cost could potentially be lowered or eliminated. As the port personnel get more experienced in securing a certain vessel, the time for mooring decreases which according to one of the interviewees would lower the mooring costs. He believes that the best case would be if the crew on board could moor the vessel themselves which would imply no extra cost for mooring. However, as Schelfn and Östergaard (1995) mention, the safety of the mooring operation is important and the crew on board the vessel would then have to be familiar with the physical conditions at the port and they would need suitable equipment. The vessel crew would probably need some help from stevedores during the first trips but after a while, it is likely that the crew on board would be able to handle the mooring operation themselves in a safe manner. There is no cost corresponding to the mooring cost for road and rail transportation and the mooring cost can thus be considered to contribute to a competitive disadvantage for sea transportation.

8.1.4 Administration costs

All vessels calling at Port of Uddevalla or Port of Gothenburg have to pay an administration fee, also called an agency fee. The interviewees explained that the agency helps the shipping company with booking pilotage, mooring, berthage and other operations in the port that the vessel arrives to. The agency cost is estimated to be the same in both Port of Uddevalla and Port of Gothenburg and together they make up 7 % of the total port charges. As with mooring costs, it was found during the interviews that the agency fee is possible to negotiate if having a returning coastal shipping service every week. This is because the administrative work would be approximately the same every week, which would allow for routines to be created and the administrative work would take less time. Standards are something that Baindur and Viegas (2011) claim are often lacking in ports and it would be beneficial for the administrative efficiency of the coastal shipping solution if standards were created. Moreover, since Paixão and Marlow (2002) mention that high administration costs can be a barrier for a successful coastal shipping solution, it would be beneficial to lower this cost. One interviewee claims that there is usually no corresponding administration cost for road and rail transport between Port of Uddevalla and Port of Gothenburg. This means that the agency fee causes an economic disadvantage for the coastal shipping solution which is another incentive for lowering the administration cost.

8.2 Transport costs

Transport costs are all costs incurred during the transportation between ports. As can be seen in Figure 8.2, transport costs make up 47 % of the total costs in the Uddevalla-Gothenburg case. In Figure 8.4, the different cost items included in the transport cost are presented.

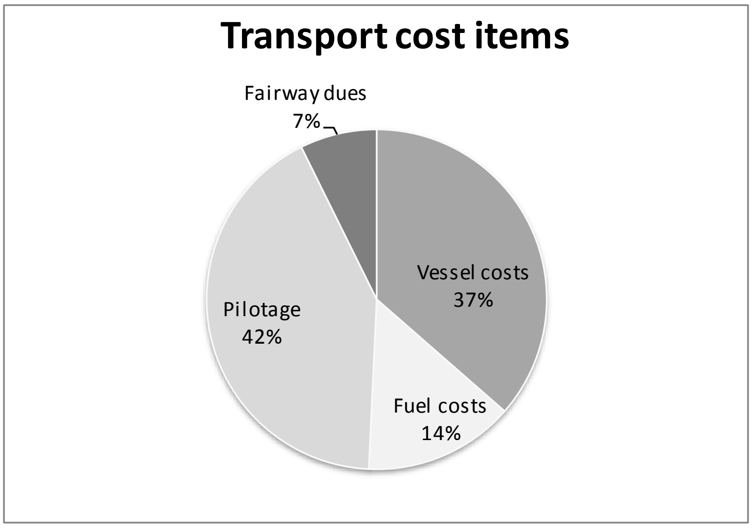

Figure 8.4. Cost items included in the transport costs.

8.2.1 Vessel costs

In this analysis, costs categorized as vessel costs are: costs for renting or buying a vessel, insurance and maintenance costs, and costs for personnel working on board the vessel. This categorization is a mix of how Ng (2009) and Sambracos and Maniati (2012) classify their vessel costs and this categorization is considered to best describe the different costs incurred in the Uddevalla-Gothenburg case. In the studied case, the option of renting a barge pusher and barges has been evaluated and the rent includes costs for personnel on board the barge pusher, insurance costs and costs related to maintenance of the vessel combination. Altogether, the costs of renting make up 37 % of the total transport costs and it is the third largest contributor to the total costs.

Vessel-related costs are largely dependent on what type of vessel that is being used and what type of cargo that is transported (Marlow and Paixão Casaca, 2007). In the Uddevalla-Gothenburg case, containers are the only type of cargo studied. But depending on the type of barge used and who the barges and barge pusher is rented from, the cost can vary considerably. The numbers used for calculating the rental cost in this case are considered to be reasonable if considering the current market situation. The optimal type of vessel to use for the coastal shipping solution has not been evaluated but to use a barge with a barge pusher seems to be a good alternative. One of the interviewees claims that the considered barge pusher consumes a bit too much fuel but the depth of the vessel is suitable for the route. Another interviewee means that the advantage of using a barge with a barge pusher is that the barge pusher can be utilized for other tasks and can generate income when the barge is being loaded and unloaded in the port. To have a setup like this requires that there are other tasks for the barge pusher available, but if there is, the high utilization would be very beneficial from an economic point of view.

The Swedish Maritime Administration (2016) claim that sea transport is a cost effective alternative to road and rail transport when transporting large volumes over long distances. The volumes of cargo transported between Uddevalla and Gothenburg today are very small compared to the volumes transported by larger ocean-going container vessels, and the distance is very short. This means that there are basically no economies of scale to be exploited and according to one of the interviewees, this is a great disadvantage of coastal shipping. However, to use a vessel with a larger capacity could be problematic due to the characteristics of the route and the small passages the vessel must be able to go through. During the interviews it was found that one possible way to increase the capacity on the considered barge is to load containers in a third layer, which equals a 50 % increase in capacity. However, if this is physically possible and if there is available cargo to fill a third layer of containers must be further evaluated. The Swedish Maritime Administration (2016) state that few actors need to transport large amounts of goods nationally in Sweden which speaks against an increase in cargo volumes. However, the proposed coastal shipping solution has an advantage in that goods are collected in Port of Uddevalla from many different actors and the total amount of goods can be higher than if only transporting goods from one actor.

If the coastal shipping solution between Port of Uddevalla and Port of Gothenburg would become a permanent solution, it could be an option to buy a vessel instead of renting. According to one of the interviewees it is not economically possible to buy a newly built vessel for the considered route, but to buy a second-hand vessel could be an alternative. It must be noticed though that in addition to the acquisition cost of the vessel there will be further costs for insurance, maintenance and personnel on board the vessel that are now included in the rent of the barge and barge pusher.

8.2.2 Fuel costs

Fuel costs are often a big part of sea transport costs (Jafarzadeh and Utne, 2014). In the studied case, fuel costs make up 14 % of the transport costs but this percentage is highly dependent on the current price for bunker fuel. In the case studies made by the Swedish Maritime Administration (2016), fuel costs varied between 10 and 25 % of the total costs of coastal shipping and it can be seen that the fuel costs in the Uddevalla-Gothenburg case fall into this interval as well. According to Jafarzadeh and Utne (2014), fuel prices are increasing and fluctuating and it is therefore very important to keep the fuel consumption low. Except from the price for bunker fuel, speed is also a factor affecting the cost of fuel (Notteboom and Cariou, 2013). In the proposed coastal shipping solution between Port of Uddevalla and Port of Gothenburg, the speed is planned to be six knots. This is a very slow speed if comparing to the speed of 22 knots that Drewry (2011) mentions as an example when describing the concept of slow-steaming. Since the transport time is already quite long, nine hours for 102 km, it is not recommended to go at an even slower speed even though this could lower the fuel cost. A longer transport time could make it necessary to handle loading and unloading of containers on inconvenient working hours when personnel costs in ports are higher. This increased handling cost could then offset the savings in fuel costs and, in line with the reasoning by Woo and Moon (2014), the total costs are instead likely to increase due to the longer transport time.

Since SECA was introduced, the requirements on fuels in sea transportation have become stricter (IMO, 2017b). All vessels within the affected area must run on low-level sulphur fuel, which according to the interviewees and Antturi et al. (2016) is more expensive than the fuel with higher levels of sulphur. According to the interviewees, many shipping companies expected fuel costs to increase considerably when SECA was first introduced. However, crude oil prices dropped at the same time as SECA was introduced and the prices for low-sulphur fuels did not become that much higher than what had been paid for the previous fuels used. One of the interviewees states that the shipping company CMA CGM barely changed their prices when SECA was introduced, but he also claims that if SECA would not have been introduced, prices could have been decreased due to the lower fuel prices.

One of the interviewees states that if using the proposed barge and barge pusher in the Uddevalla-Gothenburg case, the fuel consumption is 250 litres per kilometre. This consumption is, according to another interviewee, quite high compared to other vessels that would be possible for the route. In a similar case where a potential coastal shipping solution between Vänersborg and Gothenburg was evaluated, a vessel consuming 90 litres per hour was considered to be a possible choice (Ljungqvist et al., 2017).

The short distance on the studied route is not optimal for a coastal shipping solution. Even though opinions vary on the most competitive distance for SSS, the 102 km route between Port of Uddevalla and Port of Gothenburg is far below the average distance of 1385 km used for SSS in Europe. It can be concluded that, as the Swedish Maritime Administration (2016) claim, the savings in fuel costs of using sea transport are far too small on this short distance in order to compensate for the much higher handling costs.

8.2.3 Fees

The fees included in the cost calculation of the coastal shipping solution between Port of Uddevalla and Port of Gothenburg are pilotage fees and fairway dues. Pilotage must be used for the whole route and the cost is dependent on the transport time. In the studied case, the pilotage fee is 42 % of the transport costs which is a very large share. Compared to the case studies made by the Swedish Maritime Administration (2016) where pilotage fees together with fairway dues made up only 7 % of the total costs, the pilotage fee for the Uddevalla- Gothenburg case seems unreasonably high. However, in some of the cases studied by the Swedish Maritime Administration (2016), there are large discounts on the pilotage fee that do not apply to the route Uddevalla-Gothenburg. To lower the pilotage fee in the studied case, it is possible to apply for a PEC. During the interviews it was found that the PEC is personal and it would be necessary to apply for two certificates for two different captains in order to make the coastal shipping solution robust. The exact cost of a PEC for the studied route has not been calculated, but based on estimates from one of the interviewees, the cost for two certificates should be lower than what pilotage during only one month would cost. How much the pilotage cost can be lowered depends on the cost of the PEC, the number of years that each captain is working and the number of trips per year. It is estimated by one of the interviewees that a reduction by 95-98 % is fully realistic. This means that it would be a very good investment to apply for PECs, but what must be noticed is that since the certificate is personal, there could be additional costs in the future if a captain quits its job and a new PEC must be applied for. Moreover, one of the interviewees claims that it can be difficult to get a PEC on the studied route since there is a very narrow passage that the vessel must pass through, and usually this is not a route where vessels go.

Regarding the fairway dues, these make up 7 % of the transport costs today. The new fairway due model that is planned to take effect in 2018 will not change this percentage and the cost per container will only decrease with 1 SEK. In order to decrease the fairway due further it is necessary to use a more environmentally friendly vessel since the fairway due model provides discounts to more environmentally friendly vessels. The Swedish Maritime Administration (2016) state that the new fairway due model is likely to have a negative effect on coastal shipping in Sweden, but it can be concluded that in the Uddevalla-Gothenburg case, the new model will barely make any difference. The Swedish Maritime Administration (2016) also discusses the possibility of reducing the pilotage and fairway dues temporarily during start-ups of coastal shipping solutions in order to make coastal shipping more competitive in Sweden. In the studied case, it would be most beneficial if the pilotage fee was reduced since this fee makes up the largest cost. However, if a PEC is applied for, it would be more beneficial if the fairway dues were reduced.

8.3 External costs

As Perakis and Denisis (2008) state, external costs are difficult to quantify and it is difficult to make comparisons between different modes. In this study, the calculation tool TrExTool has been used to estimate the external costs related to environmental and social effects of the coastal shipping solution and the road and rail alternatives (see results from calculations in Appendix D). As can be seen in Figure 8.5, the calculations show that these external costs are much higher for sea transport than for road and rail transport, but it is important to notice that the calculations are based on several assumptions.

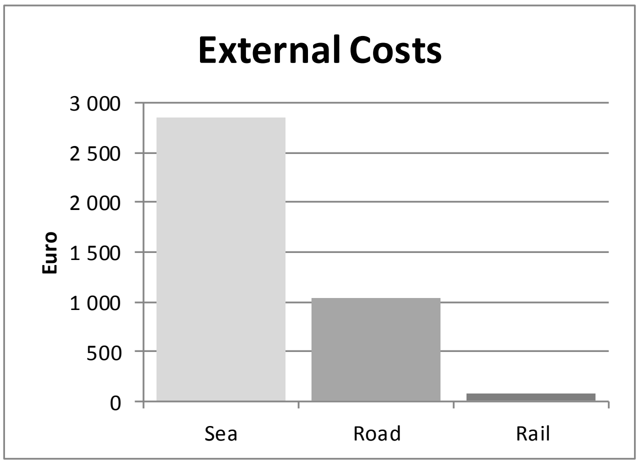

Figure 8.5. Comparison of external costs related to environmental and social effects. The diagram shows the results of the calculations made in TrExTool with a modification of the external costs for sea transport to better correspond the fuel consumption in this case (see section 2.5.5.). The calculations are based on the movement of 45 FEUs and 11 TEUs.

The high external costs of the coastal shipping solution speaks against the result from many other studies (Swedish Maritime Administration, 2016; Lu and Yan, 2015; Md Arof, 2015;

Galati et al., 2016). However, the calculations made in this study do not include external costs related to infrastructure, and the fuel consumption and NO_x emissions of the barge used in the calculations are very high compared to many other vessels. Parts of the external costs related to environment are already internalised for road transport but not for sea transport. This means that if the internalisation level of environmental-related external costs increases in the future, the cost of sea transport will increase more than the cost of road transport. However, all external costs related to infrastructure are internalised for sea transport but not for road and rail transport and many authors claim that sea transport has the lowest non-internalised external costs per tonne-kilometre compared to rail and road transport (Sambracos and Maniati, 2012; Lu and Yan, 2015, Galati et al., 2016). This could imply that the road and rail transport alternatives have higher external costs related to infrastructure than the coastal shipping solution and an increased internalisation level of these external costs could be beneficial for the competitiveness of sea transport in the future. One of the interviewees, on the other hand, claims that the external costs of sea transport are not as low as many people seem to think and he does not believe that an internalisation of external costs would make coastal shipping more competitive. The results presented in Figure 8.5 are in line with the considerations of this interviewee. Furthermore, the fact that rail transport has the lowest external costs matches the results that the Swedish Maritime Administration (2016) got in their estimations. But to fully conclude if a higher internalisation level of external costs in the future will increase the competitiveness of coastal shipping between Port of Uddevalla and Port of Gothenburg, further investigation is needed which is outside the scope of this study.

8.4 Total costs

In Figure 8.6, the total costs of coastal shipping between Port of Uddevalla and Port of Gothenburg are compared with the total costs of road and rail transport between the same destinations. See section 2.5.4 for an explanation of how the calculations were made.

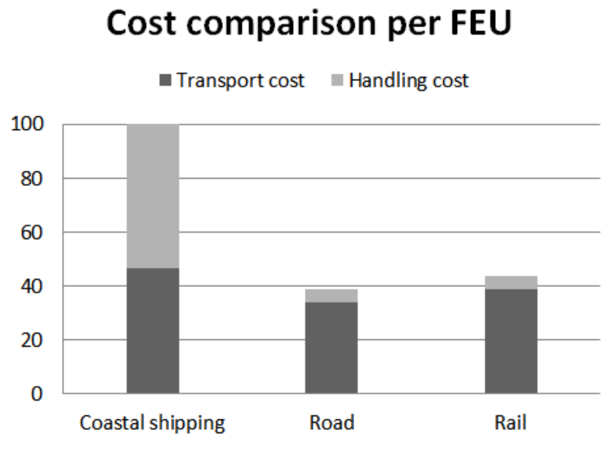

Figure 8.6. Cost comparison of coastal shipping, road and rail transport between Port of Uddevalla and Port of Gothenburg. The total cost for coastal shipping is set to index 100.

The comparison clearly shows that the cost of coastal shipping is substantially higher than the costs of the other transport modes. It can thus be concluded that the requirement to have a price for the coastal shipping solution that is equal to or lower than today's rail and road transport solution cannot be fulfilled. In the case of coastal shipping, handling costs make up the majority of the costs while for road and rail transport, handling costs are only between 11 and 12% of the total costs. The undoubtedly largest part of the handling costs are made up of costs for loading and unloading containers. In order to increase the competitiveness of coastal shipping between Port of Uddevalla and Port of Gothenburg, these costs must be decreased considerably. Port charges, mooring costs and agency costs make up much smaller shares of the handling costs and even though it would be beneficial to reduce these costs as well, the costs for loading and unloading should be considered in the first place.

The transport cost of coastal shipping is also higher than the transport costs of road and rail transport. What makes up the largest share of the transport cost of the coastal shipping solution is the cost for pilotage and the solution will not be competitive unless having a PEC. In Figure 8.7, the costs of the different transport modes are compared where the pilotage cost for sea transport is lowered by 95 %.

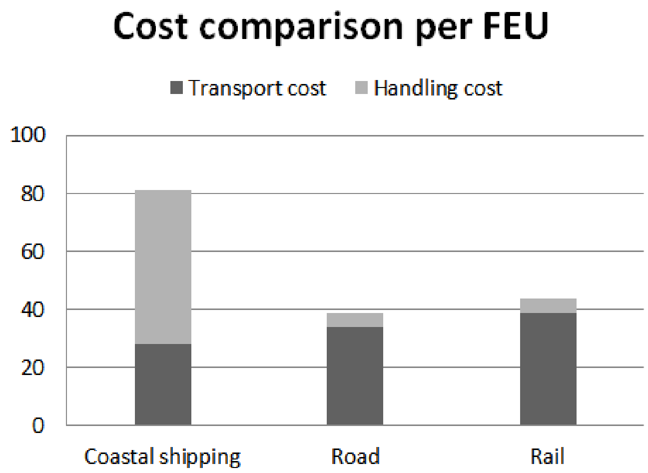

Figure 8.7. Cost comparison of coastal shipping, road and rail transport between Port of Uddevalla and Port of Gothenburg when having a PEC. The original total cost for coastal shipping without PEC equals index 100.

Figure 8.7 shows that when having a PEC, the transport cost of sea transport is lower than the road and rail transport costs. In this case, the rental charge make up the majority of the sea transport costs and in order to further lower the costs, it could be beneficial to compare different vessel alternatives. If using a different vessel, it would also be advantageous to choose a vessel with a lower fuel consumption since the current consumption is quite high and therefore costly.

In order to further decrease the cost per FEU, the load factor of the vessel could be increased. In Figure 8.8 the costs of the different transport modes are compared when having a PEC and a load factor of 100 %. It can be seen that the total costs of sea transport decreases with increased load factor, but since volumes fluctuate from week to week it is unrealistic to expect a load factor of 100 % every week. As previously mentioned, the load factor used for the calculations is 80 %.

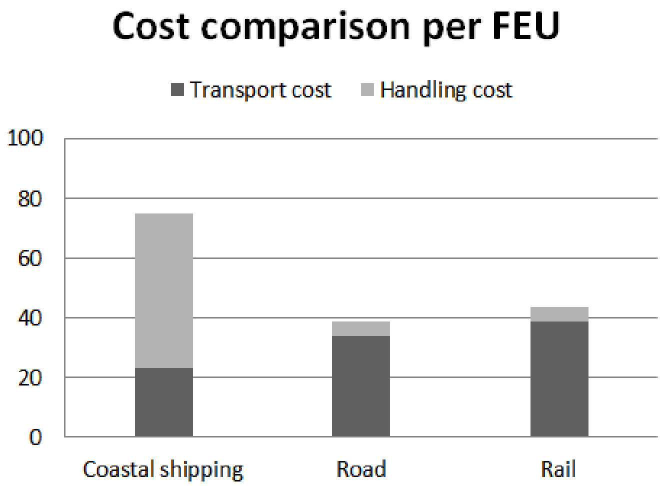

Figure 8.8. Cost comparison of coastal shipping, road and rail transport between Port of Uddevalla and Port of Gothenburg when having a PEC and a load factor of 100 %. The original total cost for coastal shipping without PEC and with 80 % load factor equals index 100.

The requirement for coastal shipping to reach the same price level as road and rail transport is far from fulfilled. Handling costs have been shown to make up the majority of the costs and since loading and unloading costs make up a very large part of the handling costs, these will be further analysed in section 11.2.

9. Fulfilment of the logistic performance requirements

The logistic requirements found when identifying performance requirements for the container transportation between Uddevalla and Gothenburg concern reliability, volume flexibility and frequency. This section will therefore evaluate the performance of a coastal shipping arrangement based on these three topics. As illustrated in Figure 9.1, the parts of the theoretical framework that concerns these issues will be used as a foundation for the analysis, together with the data collected from interviews.

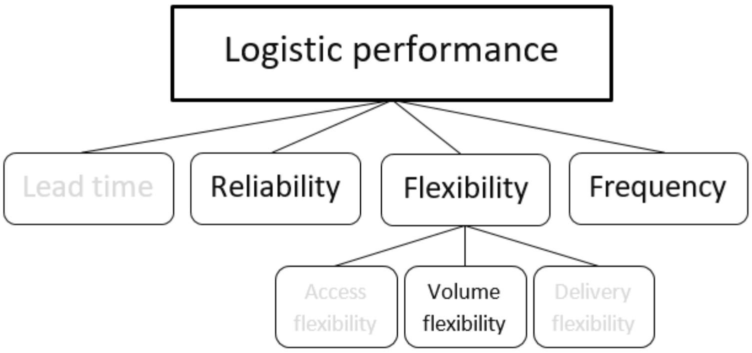

Figure 9.1. Concepts affecting the logistic performance of coastal shipping. The concepts marked with grey have not been identified as requirements for a competitive coastal shipping solution in the Uddevalla-Gothenburg case.

9.1 Reliability

The requirement identified regarding reliability was that departure and arrival must be on time, within a time frame of a few hours. First of all, it is essential that the transportation is reliable in the sense that you can be sure that the vessel actually departs and will fulfil the journey every time it is supposed to. The conclusions from earlier studies in maritime transportation diverge in this area. The Swedish Maritime Administration (2016) claim that shipping has a high reliability, but it is not clear from the report what this opinion is based on. Morales-Fusco et al. (2013) and Galati et al. (2016) on the other hand argue that the use of maritime transportation on a short distance as part of a transportation chain will make the transportation less reliable. However, this conclusion is based on the assumption that the introduction of maritime transportation on a short distance increases the complexity of the transportation chain, for example by adding another transhipment. In the case between Port of Uddevalla and Port of Gothenburg, there is already transhipment at both ports today, but to/from truck or train instead of vessel. A change from land transportation to coastal shipping will therefore not increase the complexity in that sense.

One interviewee argues that a coastal shipping solution between Uddevalla and Gothenburg will be quite dependent on weather conditions. The part of the route called Instörännan is particularly critical with a narrow passage, and the interviewee believes that this passage can only be passed through in daylight and in good weather conditions. This strengthens the view of Baindur and Viegas (2011) who state that maritime transportation is the mode that is most dependent on weather conditions. On the other hand, one of the other interviewees does not think that weather will cause many problems since the shipping is planned to go inshore and is therefore protected from the troubles that strong winds can cause at sea. Since there is no vessel traffic in the area today, it is difficult to draw any conclusions concerning how much weather conditions will affect the reliability of the transportation. But the issue cannot be ignored. In line with the reasoning of Lam and Lassa (2017), the risks and effects connected to weather needs to be assessed and investigated further. Therefore, the route should be tested with the vessel that is supposed to be used in a permanent coastal shipping solution.

It is suggested by one of the interviewees that time critical containers can be transported by truck if the vessel for some reason cannot depart on time. This demonstrates the common view that road transportation is a highly reliable mode, which is also found by Paixão and Marlow (2002). There is however some problems with road transportation regarding on-time reliability, caused by congestion on the roads to and in Gothenburg, as well as in the truck gate in Port of Gothenburg. It was discovered during the interviews that trucks sometimes have to wait for one hour in the port, while the target set up by the port operator is that the waiting time should be maximum 30 minutes. The rail transportation to Port of Gothenburg has, according to one of the interviewees, more than 90 % on-time reliability. Based on the theoretical findings, where it is described that on-time reliability of maritime transportation is generally considered to be low (Medda and Trujillo, 2010; Trujillo et al., 2011), it can be assumed that it will be difficult to reach the same level of on-time reliability with coastal shipping as with rail transportation. But the requirement regarding reliability is that the vessel arrives within a time frame of a few hours, which means that it might not be necessary to reach the same punctuality as the rail system has today. Several of the interviewees mention however that it might be necessary to run the vessel in daylight, at least in the critical passage. This adds some further requirements to the on-time reliability of the departure, since it must depart in time to pass through the critical area before it gets dark. In order to better assess the on-time reliability of the coastal shipping, further investigation is needed where the route can be tested several times. In sum, this analysis shows that a coastal shipping arrangement has a good chance of succeeding in reaching the requirements regarding reliability, but the actual transportation must be tried in order to draw firm conclusions.

9.2 Volume flexibility

The vessel considered in this case will have a load factor of 80 % with the assumed volume of 45 FEUs and 11 TEUs per departure. There is hence some room for volume flexibility. As long as the increase in volume does not exceed the maximum capacity of the vessel, there are no problems to cope with an increase in volume and the marginal cost per container for the transportation becomes quite low. However, if the volumes would exceed the maximum capacity of the vessel it may cause problems. Only a few extra containers will not motivate an added vessel departure since that would result in an extremely high marginal cost (Morales-Fusco et al., 2013). One interviewee states that if this would happen, the solution would be to send the extra containers by truck. This statement pinpoints the advantage of road transportation when it comes to volume flexibility. It is very easy for a transport buyer to use road transportation when the volume varies a lot, just as Baindur and Viegas (2011) argue. One of the interviewees explains that you pay the same price for every container shipped by truck which means that the cost of shipping containers by truck increases linearly. This is unlike coastal shipping where you have a very large start-up cost and then a lower marginal cost for every added container up to the maximum capacity.

The ability for coastal shipping to cope with a lower volume must also be considered. As Morales-Fusco et al. (2013) argue, maritime transportation performs best when the volume is quite large and constant over time. In the studied case, on the other hand, the volumes vary a great deal and, as stated by one of the interviewees, can sometimes be as little as ten containers one week. It is however possible to send few containers on the vessel, and as long as the average volume over the year is sufficient to make the arrangement economically viable, it is acceptable to have lower volumes at some departures.

From an infrastructural perspective, the coastal shipping solution can be seen as quite flexible when it comes to volume, since, just as Trujillo et al. (2011) argue, the volume can be increased a great deal without any requirements for infrastructural investments. One of the interviewees believes that there is no risk for congestion on the sea route and even if Paixão and Marlow (2002) mention that ports can have limited capacity, that will not be a problem in this case. Both ports can, according to the interviewees, handle a relatively large increase in volume. Maritime transportation has an advantage here since both rail and road transportation are already highly utilized (Trafikanalys, 2016a; Inland Navigation Europe, 2014), and one of the interviewees says that this can be seen on the congestion on the roads to Port of Gothenburg. The conclusion that can be drawn regarding volume flexibility is that as long as the average volume is sufficient to make the arrangement economically viable, the volumes are allowed to vary within the capacity limits of the vessel. If the volumes would occasionally exceed the maximum capacity of the vessel, it is possible to send the exceeding containers by truck. Hence, the requirement that the transport solution must be able to handle variations in volume can be met, but it might be necessary to send some containers by truck in extreme cases.

9.3 Frequency

Road transportation provides the highest frequency on the route between Uddevalla and Gothenburg, which is in line with the findings in literature (Paixão and Marlow, 2002). The current average of 42 containers per week means 42 departures, since each truck only takes one container at a time. As described in literature, frequency is a drawback for maritime transportation compared to road (Trujillo et al., 2011; Swedish Maritime Administration, 2016). A coastal shipping or rail arrangement will never reach the same level of frequency as road transportation, as a much larger volume is shipped with every departure (Morales-Fusco et al., 2013; Swedish Maritime Administration, 2016). But since the requirement for competitiveness on this route is at least two departures per week, there is no need for such a high frequency as road transport is providing. Since the transportation lead time is a full work day (nine hours), two departures from each port every week can be achieved either by loading and unloading during night, or by using two vessels. Due to the high cost of loading and unloading during inconvenient working hours, it was found during the interviews that working during nights or weekends is not an option. Therefore two vessels, or two barges and one barge pusher, can be used. It is enough to have one barge pusher since the pusher does not have to wait in port while the goods are loaded and unloaded, but can instead continue with the transportation of the next barge that has already been loaded. It can hence be concluded that there are no physical barriers to reaching the required frequency of two departures per week. But the arrangement must also be economically viable, which requires that there is enough demand and goods to be transported to have a frequency of two departures every week. It is assumed in this study that it is possible to fill the barge to 80 % in every trip, even if having two departures per week. It is therefore concluded that the requirement of having at least two departures from each port every week can be fulfilled.

10. Fulfilment of the environmental performance requirement

The environmental performance requirement is that the transportation with coastal shipping must in total be more environmentally friendly than road and rail transportation. The theoretical framework identifies the most common ways to assess the environmental impact from transportation, see Figure 10.1. This section will therefore evaluate the costal shipping arrangement's performance regarding energy consumption and emissions. Energy consumption and the levels of emissions have been calculated using TrExTool (see detailed description of the calculations in section 2.5.5 and the results in Appendix D) for road, rail and coastal shipping respectively. The coastal shipping calculations are based on the barge and barge pusher that were described in the case description (see section 1.2).

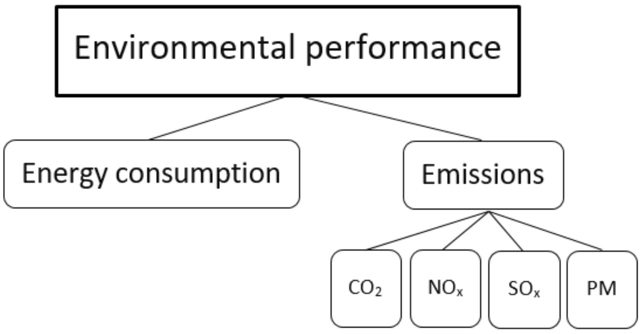

Figure 10.1. Factors to consider and measure when evaluating the environmental performance of coastal shipping.

10.1 Energy consumption

The result of the calculations using TrExTool show that coastal shipping is the alternative with the highest energy consumption, see Figure 10.2. This contradicts the findings of earlier research that maritime transportation is the most energy efficient mode of transportation (Kågeson, 2011; Castells Sanabra et al., 2014). As described by Perakis and Denisis (2008), the advantage of maritime transportation is the economies of scale, which gives low energy consumption per tonne-km when a vessel is fully loaded, especially for vessels with high capacity. Since the barge has a relatively low capacity compared to larger oceangoing vessels, not much economies of scale are exploited and the energy consumption per container becomes high. Moreover, the barge is not expected to be fully loaded in every departure due to variations in demand which further increases the energy consumption per container. The barge pusher is, according to one interviewees, estimated to consume 250 litres MDO per hour. Another interviewee claims that this is a very high fuel consumption, and therefore also energy consumption, compared to more modern vessels. A different vessel choice could reduce the energy consumption substantially and the interviewee believes that it is possible to reach a lower level than road transportation. But the energy consumption for rail transport is only 27 % of the consumption for coastal shipping in this case and even with a more energy efficient vessel, it is not guaranteed that the coastal shipping will reach the same level as rail.

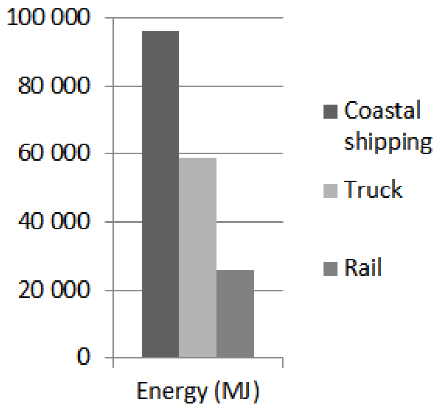

Figure 10.2. Comparison of total energy consumption for transportation between Uddevalla and Gothenburg

The barge is estimated to have an average speed of six knots. The energy consumption is generally said to decrease with reduced speed (Drewry, 2011), but in this case the speed is already rather slow and it can be assumed that a further speed reduction would give quite a modest reduction in energy consumption. The reason for this is that the elasticity in the relation between speed and energy consumption is according to Woo and Moon (2014) low at such low speeds. As already mentioned in section 8.2.2, a further speed reduction could also increase total cost and is therefore not an option. Coastal shipping, road and rail transportation use different energy sources and since the environmental impact between the energy sources differ (Bilgen, 2014), it is not enough to only measure energy consumption in order to evaluate the environmental impact of the transportations. Emissions from the different transport modes are also important to consider and these will be analysed in the next section.

10.2 Emissions

The most common emissions to measure when evaluating transportation is CO_2, NO_x, SO_x and PM (Madejska, 2013), and these are therefore the emissions considered in this study. The results of the calculations with TrExTool are illustrated in Figure 10.3 and clearly show that coastal shipping seems to be the mode that emits the highest levels of all four substances.

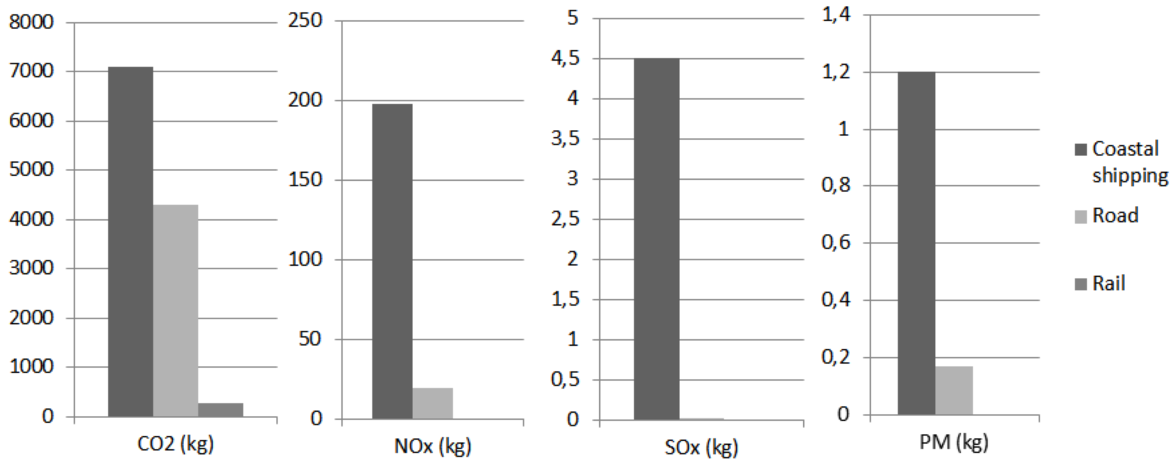

Figure 10.3. Comparison of emissions for the transportation between Uddevalla and Gothenburg

10.2.1 Carbon dioxide

Maritime transport is often referred to in literature as the mode that produces the least amount of CO_2 (Medda and Trujillo, 2010), but the results of this study indicate the opposite, that both rail and road transportation cause less CO_2 emissions for this specific case. Two reasons for this are that the barge used in the calculations is small compared to the large vessels that normally transport containers on sea, and that the barge is not fully loaded. Several interviewees argue that maritime transportation is often an environmentally competitive alternative when dealing with large volumes. As The Royal Academy of Engineering (2013) have described, the CO_2 emission per load unit gets low when large vessels are used, since the fuel consumption is subject to economies of scale and the level of CO_2 emissions is directly related to fuel consumption. But for this type of smaller vessels, the fuel consumption per load unit gets higher and therefore also the CO_2 emissions. The barge pusher has, as already explained, high fuel consumption, which is another reason why the CO_2 emissions are rather high. A different vessel choice could lower the fuel consumption substantially and thereby also the CO_2 emissions. But it would still be difficult to reach the low CO_2 emissions caused by rail, as rail in Sweden is driven by electricity with close to zero CO_2 emissions (Kågeson, 2011; Green Cargo, 2014).

10.2.2 Nitrogen oxides

The results from the calculations show that the NO_x emissions are almost ten times higher for coastal shipping than for road transport. The barge pusher used in this case is built in year 1980 and since restrictions on NO_x levels only apply to vessels built after 1990 (Castells Sanabra et al., 2014), the barge pusher has no NO_x emission limits. It has therefore been estimated that the barge pusher belongs to NO_x Tier 0, which explains the high emission levels. A vessel with NO_x Tier III would be required in order to reach the same level as road transportation (Kågeson, 2011). To reach the same level as rail, which in this case is zero, is not possible with a vessel that uses a diesel engine of today.

10.2.3 Sulphur oxides

The emissions of SO_x are also higher for the coastal shipping solution than for road and rail. This is a known problem for all vessels that use diesel for propulsion (Martínez de osés and Castells, 2009). The route studied in this case, however, belongs to a SECA and the allowed level of sulphur content in the fuel is therefore 0.1 % (IMO, 2017b). The emissions of SO_x from rail and road transportation is zero or very close to zero. This can be explained by the level of sulphur in diesel for trucks of 10 ppm (Kågeson, 2011), which is only one hundredth of the allowed sulphur content in marine diesel oil within SECA. Even if the emissions could be lowered a bit more for coastal shipping with a lower fuel consumption, the coastal shipping arrangement will not reach the same levels as road and rail.

10.2.4 Particulate matter

When looking at the emission of PM, coastal shipping has the highest emissions and the emission from rail is, once again, zero. The PM emissions for coastal shipping are 1.2 kg per 96190 MJ which corresponds to 0,045 g/kWh. This is significantly lower than the 0.2-24 g/kWh that Kågeson (2011) states is common for vessels, which is probably a result of the low-sulphur fuel used, since the level of sulphur affects the emissions of PM (Fridell and Salo, 2016). The results for road transportation lie slightly below the limit for Euro V of 0.02 g/kWh (Kågeson, 2011) which is considered to be reasonable. Even if the results for the PM emissions of coastal shipping are a bit low compared to the theoretical findings, the calculations clearly show that coastal shipping emits far more PM than both road and rail transport.

10.3 Total environmental performance

Even though all calculated emissions are higher for coastal shipping than for road and rail transportation, it is also of importance to consider where the substances are emitted. CO_2 is considered to have a global impact (Castells Sanabra et al., 2014) and hence there is no difference in impact from the CO_2 emissions made at sea or inland. NO_x has a rural impact (Castells Sanabra et al., 2014) and the NO_x emissions from coastal shipping and trucks in this case, can therefore be assumed to affect the same area, as the transportations take place quite close to each other geographically. SO_x and PM have a local impact (Castells Sanabra et al., 2014), which means that emissions closer to densely populated areas will cause greater negative effects for human health than emissions in unpopulated areas. One interviewee believes that road transport affects the local environment more than sea transport, since most of the emissions from sea transport are made in unpopulated areas, while trucks drive inland closer to populated areas. The barge pusher used in this theoretical case study will not be left in port with the engines running, so the part of the emissions that are emitted close to the port will be very small. The route is however planned to go inshore, which means that the vessel will always be close to the coast, primarily between the mainland and populated islands. It can therefore be argued that the emissions with a local impact will affect the land area along the route, even if the emissions caused by trucks are even closer to populated areas.

As mentioned earlier, there are some problems with congestion on the roads to Port of Gothenburg. This reduces the speed of the trucks and therefore causes higher levels of emissions (Medda and Trujillo, 2010). When calculating emissions for road transportation with TrExTool, the distribution between urban and rural areas was specified together with information about the share of the transportation that takes place during peak time. TrExTool uses this information to calculate the added environmental impact caused by congestion. To use coastal shipping between Uddevalla and Gothenburg instead of road transportation would reduce the number of trucks on the road and thereby reduce the congestion, just as Morales Fusco et al. (2013) argue. This means that the movement of some goods from road to maritime transport reduces the level of emissions from the remaining trucks, since they experience less congestion and do not have to emit unnecessary emissions due to waiting time in queues and slow traffic.

Several of the interviewees take for granted that the coastal shipping arrangement will be more environmentally friendly than road transportation. But as the results of this analysis show, both energy consumption and emissions of CO_2, NO_x, SO_x and PM are higher with a coastal shipping solution than with road transportation. It should be noted that these results are based on the use of a specific barge pusher, and that the results could be different with another vessel. The barge pusher's high fuel consumption and the relatively low capacity of the barge compared to container ships are two reasons that explain the negative results for coastal shipping. Just as some of the interviewees argue, rail freight in Sweden performs very well in environmental evaluations and is difficult to outperform. It is however important to point out that the emissions and energy consumption calculated in this study only concerns the actual transportation, not the handling or the environmental impact connected to the infrastructure needed, for example construction and maintenance of roads, railways and terminals. The results of this analysis confirm López-Navarro's (2014) conclusions that comparative analysis must always be made for a specific route and vessel. It cannot be assumed that maritime transportation always performs better than road and rail transportation in environmental measurements.

11. Performance improvements of the proposed coastal shipping solution

The proposed coastal shipping solution cannot fulfil all requirements for competitiveness and there must be certain performance improvements in order to make the transport solution competitive against today's road and rail transports. This chapter aims at answering the third research question regarding how the coastal shipping solution should be designed to meet the performance requirements.

11.1 Fulfilment of the identified requirements

In Table 11.1, the requirements for a competitive coastal shipping solution are presented along with the result of the previous analysis regarding if the requirements can be fulfilled or not.

Table 11.1. Fulfilment of requirements for the coastal shipping solution.

Performance requirements for a competitive coastal shipping solution between Port of Uddevalla and Port of Gothenburg		**Can the requirement be fulfilled?**
Economic performance		
Total cost	Same or lower price as today's rail and road transport solutions	No
Logistic performance		
Reliability	Departure and arrival cannot deviate more than a few hours from appointed time	Yes
Frequency	At least two departures per week from each port	Yes
Volume flexibility	The transport solution must be able to handle variations in volume	Yes
Environmental performance		
Environmental impact	The transport solution must be more environmentally friendly than road and rail transport	No

The table shows that the requirements regarding total cost and environmental impact could not be met. The most critical factors affecting these two performance areas are high costs of loading and unloading containers and an inappropriate choice of vessel. These factors will therefore be further analysed in this chapter.

11.2 Cost of loading and unloading containers

The total cost of the coastal shipping solution between Port of Uddevalla and Port of Gothenburg is a lot higher than today's transport solutions with road and rail. The absolute largest share of the costs is the cost of loading and unloading containers, and in order for the coastal shipping solution to become attractive for customers, handling costs must be reduced. This is in line with the findings by the Swedish Maritime Administration (2016) who state that the competitiveness of coastal shipping is largely affected by costs in ports when having small volumes and short distances. In order for the coastal shipping solution to reach the cost level of rail, a cost reduction of 46 % of the total cost is necessary (when having a PEC). If all this cost reduction would be applied to the cost of loading and unloading containers, this cost item would have to be reduced by 84 %. However, there are other cost items that can be reduced as well but the cost of loading and unloading is considered to have the largest potential to be reduced. As Konings (2007) and Becker et al. (2004) claim, it is more important to reduce handling costs than transport costs, and investments in cargo handling are often more profitable than investments in vessel speed. The coming sections will describe different ways that costs of loading and unloading containers can be reduced.

11.2.1 Efficiency and layout of port infrastructure

By improving the efficiency in ports, handling costs can be reduced and the competitiveness of coastal shipping can be increased (Kasypi et al., 2013; Ng, 2009). Even though Port of Uddevalla and Port of Gothenburg cannot make large investments only to facilitate the coastal shipping solution evaluated in this case, the ports should try to streamline the container handling activities as much as possible in order to reduce handling costs. One way to increase efficiency in Port of Uddevalla and Port of Gothenburg is to make sure that containers transported by a barge or another small vessel can be handled in a simple manner (Swedish Maritime Administration, 2016). According to one of the interviewees, Port of Gothenburg handles a barge in the same way as a large oceangoing vessel and the same equipment, personnel and handling time is required. Therefore, the port prefers to handle larger vessels in order to exploit economies of scale. Since there is a significant difference in size between a barge and other container ships handled in Port of Gothenburg, it seems unreasonable that a barge cannot be handled in a simpler way. According to another interviewee, the large cranes that are used in Port of Gothenburg increase the time it takes to load and unload containers since the working arm is very long. If instead using a smaller crane, similar to those used in Maasvlakte II which are suitable for barge handling, the handling time can be reduced which in turn also lowers the handling costs. It would therefore be beneficial for the coastal shipping solution if both Port of Uddevalla and Port of Gothenburg used smaller cranes. However, during the interviews it became clear that it is not economically justifiable to invest in new cranes only for the sake of this case. It is therefore recommended that Port of Gothenburg and Port of Uddevalla investigates the possibility to use older, second-hand cranes that are smaller and cheaper to use than the ones used today. Moreover, since barges have not been handled in the ports before, the coastal shipping solution must be tested in order to see what equipment that is most suitable to use in a permanent solution. According to Becker et al. (2004), it is advantageous if ports use similar handling equipment in order to facilitate for vessels that visit different ports. It would therefore be a good idea to use the same kind of cranes in both Port of Gothenburg and Port of Uddevalla.

According to one of the interviewees, it could be possible to reduce the number of people involved in the loading and unloading activity if using a smaller crane. At Maasvlakte II, two to three people are involved in the handling activity which the interviewees described is similar to the Port of Uddevalla but less than in the Port of Gothenburg where eight people are involved. It should be possible to reduce the number of people involved in the handling activity in Port of Gothenburg and if doing so, the handling costs could be reduced. Since APM Terminals are running both the operations in Port of Gothenburg and at Maasvlakte II, the competence about how to handle containers in an efficient way should be quite easily available for the Port of Gothenburg. Moreover, one of the interviewees mentioned that it should be possible to increase the utilization of the personnel working in the ports by leaving the barge in port for a whole day and letting the personnel handle the barge whenever they are not busy handling other vessels. According to another interviewee, this could reduce the need to use expensive additional personnel when there are a lot of other vessels to handle in the port. Since there will be two barges and one barge pusher in the proposed coastal shipping solution, one barge will always be left in one of the ports for at least two days before it is picked up again.

One of the interviewees claims that it is important to find innovative handling solutions which are simpler, more flexible, more reliable and cheaper. One such solution could be to set up a self-handling solution where the crew on board the vessel could load and unload containers by themselves (Swedish Maritime Administration, 2016; Baindur and Viegas, 2011). According to the interviewee, self-handling could work when having small vessels and small volumes, and preferably, quays should be small. In Port of Gothenburg, smaller vessels are today handled at a certain quay but the small vessels handled today are still much larger than the barge proposed for this coastal shipping solution. It must therefore be further investigated if the quay is sufficiently small in order for self-handling to be possible. However, since there are already cranes available at both port of Uddevalla and Port of Gothenburg, it is not considered necessary to invest in any new handling equipment that can be used for self-handling.

To decrease the cost of loading and unloading containers it is important to increase the number of moves per hour. Both Port of Uddevalla and Port of Gothenburg manage fewer moves per hour than some of the larger port terminals in the world. The 18 moves per hour in Port of Gothenburg and the 12-15 moves per hour in Port of Uddevalla are quite far from the 25-40 moves per hour that is the average in large port terminals (Ducruet et al., 2014). Even though the ports studied in this case are not as large as the ones that do 40 moves per hour, it should still be possible to increase these ports' efficiency in the handling activity. One of the interviewees has visited Maasvlakte II and states that on average 20-25 moves per hour is made at this efficient terminal and that this is the standard in Dutch ports. Port of Gothenburg and

Port of Uddevalla should be able to reach similar numbers since the loading and unloading activity is one of the few activities that are not automated at Maasvlakte II and automation is thus not required in order to reach 20-25 moves per hour. According to Kasypi et al. (2013), experienced crane operators are more productive and perform a higher number of moves per hour than less experienced crane operators. This theory is strengthened by the fact that the most experienced crane operator in Port of Uddevalla is, according to one of the interviewees, able to do 17 moves per hour, while 12-15 is the average for the other crane operators in this port. Hence, it is considered possible to increase the number of moves per hour in Port of Uddevalla when all crane operators get more experience in handling containers. In Port of Gothenburg on the other hand, one interviewee states that containers are often handled and the crane operators can be considered to be experienced already. It is not likely that the number of moves per hour can be increased very much in this port just by increasing the level of experience.

To have a port layout that is suitably planned for efficient loading and unloading of containers can increase the productivity and hence also decrease the cost of this activity (Kasypi et al., 2013). During the interviews it was found that the ports in this case cannot make any major adjustments in their port infrastructure only to suit the coastal shipping solution, but it would be possible to increase the efficiency by using the concept of lean. By using lean, wastes could be eliminated from different operations in the ports which would increase the port productivity and reduce costs (Marlow and Paixão Casaca, 2003). Not only the loading and unloading activities would benefit from implementing lean, the productivity of other operations could be increased as well. By increasing the overall port productivity, port costs could be lowered which would benefit the coastal shipping solution. One part of lean is to standardise processes and at Maasvlakte II it has been successful to use standards and instructions for the handling activities (APM Terminals, 2017). Port of Uddevalla and Port of Gothenburg would also benefit from developing such standards so that all involved personnel are performing tasks in the same, efficient way. It is recommended that both Port of Uddevalla and Port of Gothenburg starts applying more of the lean concept in their daily operations, but since this can be quite an extensive work, it should be further investigated how lean is best implemented in the ports.

11.2.2 Board-to-board transhipment

To move containers directly from a barge onto a larger oceangoing vessel would significantly reduce the number of moves in the transhipment operation. To have a board-to-board transhipment would be very efficient in the coastal shipping solution since the cost of loading and unloading containers makes up such a large part of the total costs. However, as Konings (2007) mentions, a solution like this is often very complex from a logistical perspective and many of the interviewees are also very sceptic towards a board-to-board transhipment. Two of the interviewees do not think it is technically possible to load directly from a barge to a larger vessel by using the existing cranes in the ports. Another two interviewees state that board-to-board transhipment has been performed in Port of Gothenburg, but it happens very rarely. Yet another interviewee argues that it could be possible to perform a board-to-board transhipment if placing the barge next to the oceangoing vessel, in parallel to the quay, but he do not think that would be a successful solution because the barge would have to be moved between many oceangoing vessels since the containers on the barge will have different destinations. Another interviewee also mentions the complexity with having different destinations and he states that since every container has a special place in each oceangoing vessel where it must be placed, a board-to-board transhipment would be extremely complicated. Moreover, as Konings (2007) states, a board-to-board transhipment requires that all involved vessels port calls coincide and even though the barge can be left in the port for many hours, it is not sure that the oceangoing vessels will call at the port the same day. Thus, it can be concluded that the complexity of a board-to-board transhipment is significant and there would probably not be any cost advantages in trying to load containers directly from the barge to the oceangoing vessels. It is therefore not recommended to use board-to-board transhipment for the coastal shipping solution.

11.2.3 Automation

To automate activities in ports can be very effective in order to reduce costs (Perakis and Denisis, 2008). Both physical operations and information processes can be automated and this is something that has been proven to work very well at Maasvlakte II. At this terminal, very efficient handling operations have been possible to establish by using automation and at the same time, electronic pre-notifications from barges arriving at the port have been useful in further increasing the productivity (APM Terminals, 2017). According to one of the interviewees, it is necessary to be more innovative regarding the loading and unloading activities in Port of Uddevalla and Port of Gothenburg in order to reduce the related costs. The interviewee states that to use automation could be one way to do this. However, to increase the level of automation in the handling activities in the ports would imply very large investments, and as previously mentioned, it was found during the interviews that large investments cannot be made in this case. It could, on the other hand, be possible to start using electronic pre-notifications in order to better prepare the personnel in the ports on the unloading of containers. If the personnel can plan the handling activities better it could be possible to decrease the time it takes to handle containers and then also decrease the handling costs.

11.2.4 Price structure

As the Swedish Maritime Administration (2016) state, the economic performance of coastal shipping can be improved by reconsidering the ports' price structures. One of the interviewees mentions that since neither Port of Uddevalla nor Port of Gothenburg have been involved in any similar coastal shipping solutions before, there are no set tariffs that can be used for the loading and unloading of containers onto/off a barge and there is room for price negotiations. According to two other interviewees, prices charged are specific for each shipping company and are decided in contracts. In this study, the costs of loading and unloading containers have been based on the handling of larger container vessels since, according to one of the interviewees, the ports do not know how much loading and unloading would cost for a barge. It is likely that the container handling could be performed in a simpler and cheaper way for a barge than for a large oceangoing vessel and prices are thus likely to be cheaper for a barge.

According to two of the interviewees, it should be possible to change the price structures in the ports, especially when it comes to the transhipment in Port of Gothenburg. One of them states that almost no transhipments from vessel to vessel are made in Port of Gothenburg today and the other one claims that in order for the coastal shipping solution to be competitive, the port must think differently regarding transhipment and handling. One of the interviewees suggests that Port of Gothenburg and Port of Uddevalla should charge similarly as Dutch ports where feeder vessels are not charged any port charges. According to another interviewee, the cost of loading and unloading containers is between 60-80 % cheaper in Dutch ports than in Port of Uddevalla and Port of Gothenburg. Two of the interviewees claim that the Swedish ports should use similar price structures as the Dutch ports in order to make the coastal shipping solution a more economically viable alternative to road and rail transport. If the prices for the loading and unloading activities could be lowered as much as 80 %, this would be very good for the competitiveness of the coastal shipping solution and it would only be slightly more expensive than the rail transport alternative. However, to change the price structures implies some practical implications for the ports which are further described in section 12.3.

11.2.5 Measures to decrease the cost of loading and unloading containers in Port of Uddevalla and Port of Gothenburg

This chapter has presented several different measures on how costs of loading and unloading containers can be reduced. In Table 11.2, these measures are summarized and recommendations of what each port should focus on are presented.

Table 11.2. Measures to decrease the cost of loading and unloading containers in Port of Uddevalla and Port of Gothenburg.

Measures to decrease the cost of loading and unloading containers		
	Port of Uddevalla	**Port of Gothenburg**
Efficiency and layout		
	Use smaller cranes suitable for a small vessel	Use smaller cranes suitable for a small vessel
	Increase crane operator's experience in handling containers	Reduce the number of people involved in the loading and unloading activity
	Implement lean	Implement lean
Automation		
	Start using electronic pre-notifications	Start using electronic pre-notifications
Price structure		
	Change price structures according to Dutch ports	Change price structures according to Dutch ports

11.3 Choice of vessel for improving environmental performance

The emission calculations in sections 10.1 and 10.2 showed that coastal shipping had the highest energy consumption and emitted the highest level of all measured substances, while rail transport performed best in both energy consumption and emissions. The extraordinary results of rail transport is, as already mentioned, a result of that electricity in Sweden has close to zero emissions (Kågeson, 2011). But even if rail transport shows a very good environmental performance in this study, it must be emphasized that the rail network in Sweden is already highly utilized (Trafikanalys, 2016a). An extension of the rail network might be necessary if the volumes of goods on rail would increase, which would undoubtedly cause a large environmental impact, and also high costs. This leads to the result that even if rail is currently the best option from an environmental perspective, coastal shipping can be a viable option if the environmental performance is better than for road transport. The rest of this section will therefore compare coastal shipping mainly with road transport.

From the results of the emission calculations in section 10.2, it is obvious that if the coastal shipping solution should have a chance to become more environmentally friendly than road transport, a different vessel must be used. Vessel design parameters that can reduce the energy consumption and emissions will therefore be analysed in this section.

11.3.1 The importance of vessel choice

Except for the environmental requirements, there are economic constraints connected to the choice of vessel, since the coastal shipping solution cannot be more costly than road transport. To keep the costs low, one of the interviewees claims that it is not possible to use a newly built vessel. To use a barge pusher and two barges has been promoted by several interviewees as a suitable setup, which is in line with the statement by Konings (2007). The barge and barge pusher setup is especially suitable in this case since one barge can be left in port for unloading and loading while the barge pusher transports the other barge. If ordinary vessels were to be used, it could be necessary to have two vessels in order to reach the required frequency without loading or unloading during nights or weekends, which would bring additional costs.

The decision of vessel capacity is as the Swedish Maritime Administration (2016) and Braekers et al. (2013) argue an important decision that must be considered carefully, since it affects the energy efficiency and thereby both the costs and the environmental performance. It has been assumed in this study that the volume will be 45 FEUs and 11 TEUs per trip in both directions, corresponding to 101 TEUs in each trip. Before deciding on a suitable capacity for the case in this study, it must be investigated more thoroughly what volumes of goods that can be expected. The capacity must be adapted so that load factor, and thereby the energy efficiency, is high enough, while also having room for volume flexibility since this is a requirement from the actors. If the chosen vessel would turn out to have too low capacity, there will not be room for all goods and the volume flexibility will not be good enough. Then, it could be necessary to always send containers by truck which is not a wanted solution. On the other hand, if the vessel capacity is too high, the load factor will be low which gives lower energy efficiency since it is not efficient to transport few containers on a too large vessel. This would increase the environmental impact, and the transportation cost, per container. The environmental performance of the coastal shipping solution will be better if the volumes can become higher than the assumed volumes in this study. This means that a larger vessel could be used, which usually gives a lower fuel consumption per tonne-km at a given load factor (Swedish Maritime Administration, 2016).

It is important to have a long term perspective when taking decisions about vessel type. It was highlighted by one of the interviewees that the development of vessels is slower than for trucks, just as the Swedish Maritime Administration (2016) and the Royal Academy of Engineering (2013) stated in their reports, due to lower production volumes and longer depreciation time. This makes it important to take into consideration the possibility that the energy efficiency and environmental performance of trucks will continue to improve. As Elgohary et al. (2015) mention, there is also a possibility that the emission limits for shipping will become stricter. When a vessel for the coastal shipping solution has been selected it might be expensive, or even impossible, to change to another vessel in the near future. The selected vessel must therefore be able to compete with the next generation of trucks as well, in order for the coastal shipping arrangement to continue to be seen as a competitive option.

11.3.2 Diesel vessels

As described earlier, the barge pusher considered in the theoretical case is built in 1980 and has a high fuel consumption of 250 litres MDO per hour, at the planned speed of six knots. A newer vessel is according to one of the interviewees likely to have significantly lower fuel consumption, as a result of a better engine and design. This is in line with the statements by the Royal Academy of Engineering (2013) who argue that new technologies can increase the energy efficiency. The emission of CO_2 is directly dependent on the fuel consumption and in order to reach the same level of CO_2 emission per container as road transport, the fuel consumption must be reduced with approximately 40 %, which corresponds to a reduction of 100 litres per hour. This means that the fuel consumption should be 150 litres per hour with the same speed and capacity. A 40% reduction in fuel consumption can probably be reached with a different vessel, and it is likely that an even lower consumption can be reached since Ljungqvist et al. (2017) have estimated that a vessel suitable for coastal shipping with the capacity of 96 TEUs will have a fuel consumption of 90 litres per hour. One of the interviewees believes that this is a reasonable estimation and it is therefore assumed that the fuel consumption with another vessel can be reduced with at least 50 %, to 125 litres per hour. This results in lower CO_2 emissions for coastal shipping than for road transport.

The emissions of NO_x, SO_x and PM are assumed to decrease linearly with reduced fuel consumption, but the emissions can be further reduced with other measures. The emissions of NO_x would be reduced from 198 kg to approximately 99 kg with a 50 % reduction in fuel consumption. This is still a great deal higher than the NO_x emissions from road transport. The barge pusher used for calculations belongs to NO_x Tier 0, which means that it has no catalyst system that reduces NO_x emissions. Both Wik and Niemi (2016) and the Royal Academy of Engineering (2013) claim that the NO_x emissions can be reduced by at least 80 % with the use of SCR technologies, which would give a total NO_x emission of approximately 20 kg, compared to 19 kg with road transport. A vessel with a fuel consumption of 125 litres per hour and the latest SCR systems could hence reach approximately the same level of NO_x emission as road transport.

The fuel considered in the calculations is a low sulphur fuel with 0.1 % sulphur content, which is required since the studied route is in a SECA. But the emissions of SO_x are despite this 450 times higher than the emissions from road transport. A 50 % reduction in fuel consumption would bring a significant reduction in SO_x emissions, but the levels would still be a lot higher than for road. A fuel oil with even lower sulphur content is not available, but to use HFO with higher sulphur content in combination with a scrubber could, according to Fridell and Salo (2016), give lower emissions. However, even if the scrubber would reduce the emissions by 99 % as in the study by Fridell and Salo (2016), it would still result in SO_x emissions that are 75 times higher than for road transport.

The low sulphur content in the fuel results in a relatively low level of PM emissions compared to when using HFO, but the PM emissions are still higher than for road transport. To use a vessel with a scrubber instead would not make any difference, since Fridell and Salo (2016) show that using a vessel with a scrubber gives approximately the same level of PM emissions as low sulphur fuel. A 50 % reduction of PM emissions due to reduced fuel consumption would result in a total PM emission of 0.6 kg. It is assumed that the barge pusher has no electrostatic filter today and according to Elgohary et al. (2015), an additional 85 % reduction in PM could be possible with an electrostatic filter. This would result in 0.09 kg total PM emissions, which is better than 0.17 kg emitted by road transport. It is however not stated in the study by Elgohary et al. (2015) under what circumstances the reduction can be as high as 85 %. It can therefore not be assumed that it is possible to lower the PM emissions to this level, but to install a filter would reduce the emissions to some degree and this option should be investigated further when selecting a vessel for the coastal shipping arrangement.

The calculations show that it will not be possible to find a vessel with a diesel engine that has lower SO_x emissions than the corresponding road solution. But with an energy efficient vessel and the latest gas cleaning systems, the levels of NO_x and PM can probably reach the same levels as road transport, while the emissions of CO_2 can become lower than for road transport.

11.3.3 Alternative energy sources

Several authors believe that LNG is the fuel that will grow the most in usage in the future (Wik and Niemi, 2016; Elgohary et al., 2015) and some of the interviewees say that this pattern can be seen in the interest from Swedish shipping companies as well. The emission data presented by the Royal Academy of Engineering (2013) and Elgohary et al. (2015) clearly demonstrate that the environmental impact from an LNG vessel would be lower than for a diesel vessel and it would make coastal shipping a better alternative than road transport, when comparing with trucks of today. But even if LNG vessels exist today, they cannot be considered as options for the case in this study. The interviewees confirm the problem with availability and infrastructure that is brought up by Wik and Niemi (2016) and the Royal Academy of Engineering (2013), that there is currently no availability in the ports considered in this case. Elgohary et al. (2015) argue that changing to LNG would result in economic savings due to a lower fuel price. But even if the fuel price would be lower, investing in, or renting, a newer LNG vessel would be significantly more expensive than an ordinary diesel vessel and the interviewees unanimously discard this idea as a possible solution today. LNG could be a possible solution for a coastal shipping arrangement between Uddevalla and Gothenburg sometime in the future, but as Wik and Niemi (2016) highlight, the reduction in CO_2 emissions from using LNG is not very large. The development of trucks is constantly moving forward and there is a possibility that the CO_2 reduction that LNG brings to coastal shipping will not be enough to outperform road transport in the future.

Methanol is another alternative that reduces the emissions of NO_x, SO_x and PM (Andersson and Márquez Salazar, 2015) and a coastal shipping arrangement with a vessel that uses methanol for propulsion could therefore result in a better environmental performance than road transport. Since methanol in Sweden can be produced from renewable sources (Andersson and Márquez Salazar, 2015), there is a significant reduction of total CO_2 emissions compared to current fuels. The interviewees highlight the benefits that methanol propulsion could have in Sweden, but one of the interviewees mentions that it has so far only been tested by Stena Line on one of their vessels. To convert a vessel to methanol propulsion would mean a large financial investment, which as already mentioned is not an option since the investment costs need to be kept low. So even if methanol would give large environmental benefits, this solution is not possible today. It should however be considered as a possible option in the future.

Several of the interviewees mention battery propulsion as a possible solution in the future that would give an environmentally friendly coastal shipping solution. The batteries would be charged with the same electricity in Sweden that is used for the railways, which results in very low emissions. Therefore, this option has the potential to outperform road transport and reach the same environmental performance as rail transport. But, just as for LNG and methanol, battery propulsion is not available yet. The Royal Academy of Engineering (2013) argue however that with further progress in the development of batteries, it is likely to become a viable option primarily for small vessels, which is suitable for this case.

12. Discussion

In this chapter, the findings of this study will be discussed and compared to findings of other studies. Theoretical contributions and practical implications will be presented, and the quality of the study will be discussed.

12.1 Discussion of the findings

The results of this study both confirm and contradict the theoretical findings of coastal shipping. Yang et al. (2014) found that cost and time are the two main factors that influence if a shipping company chooses coastal shipping as their transport solution or not. This study shows that cost is a very important factor, but that lead time is not that critical. In this study, high reliability, frequency and volume flexibility were of more interest for the involved actors than lead time. However, the findings of Yang et al. (2014) are not only contradicted by this study. Also Perakis and Denisis (2008) and the Swedish Maritime Administration (2016), claim that a short lead time is usually not a priority in maritime transportation. This study indicates that coastal shipping has a much longer transport time than road transport and if time is of importance, it is not likely that coastal shipping is chosen as the preferred transport solution.

Regarding economic performance, the Swedish Maritime Administration (2016) found that it is difficult to setup a coastal shipping solution in Sweden that is competitive against road and rail transport. The main obstacle found was the high loading and unloading costs. This study is in line with the findings of the Swedish Maritime Administration (2016) since the cost of loading and unloading containers in Port of Uddevalla and Port of Gothenburg made up the absolute largest share of the total costs. Perakis and Denisis (2008) found that the competitiveness of coastal shipping usually increases with increased distance due to economies of scale and saving in fuel costs. In the studied case, the distance is very short, only 102 km, but the findings show that if having a PEC, the transport costs are lower for the coastal shipping solution than for road and rail transport. This means that the findings of Perakis and Denisis (2008) are also true in this case since if the distance would be longer, there would be larger savings from transport costs and the handling costs would be distributed over a longer distance.

Many authors state that maritime transport is more environmentally friendly than road transport (Galati et al., 2016; Morales-Fusco et al., 2013; Perakis and Denisis, 2008; Medda and Trujillo, 2010). This study contradicts these findings since, with the proposed barge and barge pusher, all emissions were worse than for road transport. The high emissions are a result of the barge pusher's high fuel consumption, the small volumes and the short distance considered in this case. If a more fuel efficient vessel would be used, the emissions of CO_2 could be reduced to a level that is more environmentally friendly than for road transport. It can, however, be questioned that many authors state that maritime transport always is an environmentally friendlier mode of transport than road and rail, without explaining the variations of emissions from different pollutants. Even if the emissions of CO_2 are often lower in maritime transport, there can be high emission levels of especially SO_x which make it questionable to state that the environment benefits from using maritime transport. It should be noted, however, that only emissions during the transport of containers have been included in the calculations in this study. In order to get a complete assessment of the environmental impact from the coastal shipping solution, emissions from other factors such as the handling activities and building of infrastructure should also be considered. Other environmental-related effects regarding for instance the coastal shipping solution's impact on the marine life are also important to evaluate for a complete assessment of the environmental performance. There are also social factors such as noise and visual intrusion that could be assessed in order to evaluate the sustainability of the transport solution.

If considering the coastal shipping solution between Port of Uddevalla and Port of Gothenburg, this distance is only a small part of the total distance that the goods are transported. This means that both positive and negative effects from the coastal shipping will have a very small impact when considering the total transportation from origin to destination. However, if the coastal shipping solution is used over a long period of time, the positive or negative effects will add up and be more significant. The main benefit of the proposed coastal shipping solution is the reduction in road congestion that it would bring. Congestion is a big problem today, especially in the city of Gothenburg and in the Port of Gothenburg. By using coastal shipping to a larger extent, the number of trucks on the roads could be reduced. Moreover, if moving some freight from land to sea, the road and rail infrastructure do not have to be expanded at the same rate as if all freight was transported with road and rail transport. In this study, no calculations have been made on what effects the new transport solution would have on the road congestion. It is therefore suggested that the effects on congestion are further investigated in future research.

Since the cost of coastal shipping between Port of Uddevalla and Port of Gothenburg needs to be reduced considerably before it reaches the cost level of road and rail transport, it will be difficult for the coastal shipping solution to compete on price. Moreover, the barge which was first proposed for this case has a larger environmental impact than both road and rail transport, which means that customers neither have any economic or environmental incentives to switch to the coastal shipping solution. With today's technology, it will be very difficult for the coastal shipping solution to be as environmentally friendly as rail transport, but since the rail network in Sweden is already highly utilized there is a need to find new transport solutions. The coastal shipping solution must therefore be more environmentally friendly than road transport in order to create an environmental incentive for customers to choose this transport solution. It is likely that all emissions except from SO_x are possible to reduce if using another vessel than the barge, and it is therefore suggested that possible vessels for this route are further investigated in future research. If the coastal shipping solution could be marketed as more environmentally friendly than the road transport between Port of Uddevalla and Port of Gothenburg, some customers would perhaps be willing to pay a little extra for this transport solution. Then it could be possible to have a price level for the coastal shipping solution which is slightly higher than for road transport.

12.2 Theoretical contributions

In order to be able to answer the purpose and research questions of this study, theoretical frameworks of economic, logistic and environmental performance of coastal shipping have been developed by combining theoretical findings from many different authors within the maritime transport sector (see Figure 3.1, 4.1 and 5.1). To get a broad overview of what factors to consider in an evaluation of coastal shipping, these theoretical frameworks are possible to apply in other studies as well and are therefore contributions to theory. Another theoretical contribution is the performance factors included in the list of requirements (see Table 7.2), i.e. total cost, reliability, frequency, volume flexibility and environmental impact. It is likely that these factors are important for the competitiveness of coastal shipping in other, similar cases as well, but the exact requirements for each performance factor will vary from case to case. The calculation model developed for calculating economic performance of coastal shipping is another contribution to theory that this study has resulted in. This model is considered to be useful in evaluating the economic performance of other coastal shipping solutions in Sweden.

12.3 Practical implications

The findings of this study result in practical implications mainly for ports, transport operators, authorities and end customers. Ports must evaluate if it is possible to reduce the handling costs or change the price structures for coastal shipping. If ports and transport operators would see a business opportunity in using coastal shipping over land-based transport, there is a large potential for an increased use of coastal shipping. Since Sweden has a long coastline, it is possible to use coastal shipping on many different routes and this could result in increased, regular traffic at the Swedish ports. By moving freight from land to sea, the congestion in ports would be reduced which could increase the port efficiency. Ports must therefore evaluate if this increased efficiency makes it possible to change the prices for coastal shipping, in order to create more incentives for transport operators to use this transport solution. It is also up to the transport operators to negotiate with the ports in order to lower the prices. Transport operators also need to investigate what vessels that are suitable to use on the route. The vessels must be more fuel-efficient than the barge pusher studied in this case and they must be suitable in terms of capacity and size to fit the cargo volumes and the specific characteristics of the route. Here, it might be necessary for authorities to investigate the possibilities to apply control measures that encourage transport operators to use more environmentally friendly vessels. If it is possible to make the coastal shipping solution between Port of Uddevalla and Port of Gothenburg more environmentally friendly than road transport, transport operators must evaluate if their customers are willing to pay extra for a more environmentally friendly solution or if the prices must be lower in order for them to choose this transport solution. The end customers in the transport chain are considered to have a large impact on this decision. If the end customers are informed about that the products they are about to buy have been transported in an environmentally friendly way, they might be willing to pay more for this product than for a similar product with a larger environmental impact. It is then crucial that the end customer is informed about these environmental benefits of the product and the transport operator must therefore communicate this information through the transport chain.

12.4 Quality of the study

The quality or trustworthiness of a qualitative study can be evaluated using the four criteria credibility, dependability, transferability and confirmability (Bryman and Bell, 2015). These criteria are related to the criteria validity and reliability that are commonly used in quantitative studies, but due to the differences between qualitative and quantitative studies, Denscombe (2014) recommend that these four criteria are used instead. The quality assessment of this study is therefore divided by these four criteria below.

12.4.1 Credibility

Most data used in this study has been of qualitative nature. Denscombe (2014) describe that evaluation of the credibility of qualitative data can be problematic, since it is usually difficult to show that the data used in a study is completely accurate. However, Denscombe (2014) describes that the researcher can show the reader why the data is likely to be accurate. In this study, many different actors involved in the case have been interviewed, and two researchers have been present when interviewing the actors and involved in analysing the data. Different theoretical perspectives have been applied by taking into consideration contradicting theories when these have been found. To use multiple data sources, theoretical perspectives and observers in this way is called triangulation and it strengthens the accuracy of the data (Bryman and Bell, 2015).

There is always a risk that organisations like the Swedish Maritime Administration have a vested interest when publishing reports and using such reports could reduce the credibility of the research. The reports used in this study have therefore been critically reviewed. Background data and methodologies used in different reports have been examined, always taking into account that the writers can have a particular opinion that they want to spread. The individuals interviewed in the study also represent different companies and organisations with internal goals, and the same critical examination has therefore been applied to the qualitative data collected at interviews.

12.4.2 Dependability

The dependability, also called reliability, of a study can be described as the question if someone else who conducted the same research would have got the same results and reached the same conclusions (Denscombe, 2014). The methods and procedures used in this study have been described in detail in Chapter 2 and the reader can hence follow the methodology step by step, evaluate all the decisions made and replicate the study. This strengthens the dependability of the study, but just as Denscombe (2014) argues, it is probably impossible to know if someone else would have reached the same conclusions. Most of the interviews were recorded in order to assure that no information was lost or misinterpreted. This strengthens the reliability of the study, but it could have been even more reliable if all interviews were recorded and transcribed.

12.4.3 Transferability

Transferability is a term used to describe if the findings of a study can be generalized to other studies and contexts (Denscombe, 2014). The theoretical case in this study and its prerequisites are described in detail in section 1.2, which according to Denscombe (2014) is important to help the reader evaluate if the contributions from this study are applicable to another specific case. This study focuses on a specific case and is mainly built upon qualitative research. The transferability is according to Bryman and Bell (2015) often a problem for this type of research where small samples and case studies are used. The transferability of this study is however strengthened by the literature review based on published research and the spread of the references used. The theoretical frameworks are based on general theory concerning maritime transportation on short distances and can therefore be applied on other routes in Sweden, and in other countries as well if adapted to local regulations. The economic calculation model that is one of the contributions of this study has already, before this report was finalized, been used for cost calculations in another similar case, which proves that the model is transferable to other cases of coastal shipping in Sweden.

12.4.4 Confirmability

Confirmability relates to objectivity and to what degree the findings of a study are free from influence of the researchers conducting the study (Denscombe, 2014). Bryman and Bell (2015) state that it is impossible to reach complete objectivity in qualitative research, but it is important that the researchers as much as possible avoid personal values to influence the conduction and findings of the study. The authors of this report have no personal gains of reaching a specific result and can therefore be considered to have acted in what Bryman and Bell (2015) describe as good faith. All data that have been discovered during interviews have been considered and contradicting theories or data have been analysed further to find reasons for the contradictions.

13. Conclusions

The purpose of this study was to evaluate if and how coastal shipping of containers between Port of Uddevalla and Port of Gothenburg can be a competitive alternative to rail and road transportation. To answer the purpose, three research questions were formulated which aimed at evaluating the economic, logistic and environmental performance of this coastal shipping solution. Theoretical frameworks for each performance area have been developed to guide in the evaluation process of the theoretical case studied in this report. These frameworks can be useful in evaluating the performance of other coastal shipping solutions as well and are therefore contributions to theory. To answer the first research question, a list of requirements for a competitive coastal shipping solution was developed. This list revealed that there are requirements regarding total cost, reliability, frequency, volume flexibility and environmental impact. It is likely that there are requirements within these areas in other similar cases as well and this list of requirements is hence also a theoretical contribution. Moreover, another contribution to theory is the economic performance calculation model for coastal shipping that was developed during this study.

To answer the second research question, the performance of the theoretical case was calculated and qualitatively assessed which showed that all requirements except from the ones regarding total cost and environmental impact could be met. It was found that the costs of loading and unloading containers make up a significant share of the total costs, and that the environmental impact from the barge pusher that was suggested in the theoretical case, was considerably higher than for road and rail transport between Port of Uddevalla and Port of Gothenburg. To answer the third research question, different approaches of how costs of loading and unloading can be reduced, as well as different vessel choices were investigated further. The analysis showed that there are substantial barriers to reach the same cost level as road and rail transport. The costs of loading and unloading would need to be reduced by 84 % in order to meet the total cost requirement. It is likely that the costs can be reduced, but since the ports included in this case do not offer barge handling services today, further research is needed to investigate if this substantial cost reduction is possible. Regarding environmental impact, it was found that the levels of CO_2 emissions are possible to reduce below the levels of road transport if using a more fuel-efficient diesel vessel. Emissions of NO_x and PM are possible to reduce to the same levels as road transport with the use of gas cleaning systems, but without large investments in new vessels, the emissions of SO_x are not possible to reduce to this degree. Finally, the purpose of this study can be answered. A coastal shipping solution of containers between Port of Uddevalla and Port of Gothenburg can only be competitive if costs of loading and unloading are reduced, and if fuel-efficient vessels with gas cleaning systems are used.

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Appendices

Appendix A - Example of an interview guide

This appendix shows an example of an interview guide that was used to collect data about the case in this study. Some questions were changed or eliminated depending on the interviewees' areas of expertise.

Background

- Can we record the interview?
- What is your role in the company?
- What are your areas of expertise?
- If you share any sensitive information that you don't want to be public, please let us know.

Requirements for a competitive coastal shipping solution

The questions in this section aim at providing a basis for answering the first research question.

Economic performance

- What cost level, compared to road and rail transport, must the coastal shipping solution reach to be an attractive alternative? (same cost level/cheaper etc.)
    - Port charges?
    - Transport costs?
    - Fees?
    - Pilotage?
    - Fairway dues?
    - Subsidies?

Logistic performance

- What logistic performance must the coastal shipping solution reach to be an attractive alternative?
    - How important is short lead time (handling time + transport time) for an attractive coastal shipping between Uddevalla and Gothenburg? Why is it important/not important?
    - How important is reliability? Why is it important/not important?
    - What is the required frequency of departure? Why?
    - Do you think there is enough goods in circulation to make coastal shipping between Uddevalla and Gothenburg attractive?
    - How important is flexibility (volume, time of arrival, destination)?

Environmental performance

- What environmental performance must the coastal shipping solution reach to be an attractive alternative?
    - Emission levels (CO_2, SO_x, NO_x, PM)?
    - Fuel consumption?

- Energy consumption?
- Internalization grade of external costs?

The coastal shipping solution's prerequisites for meeting the requirements

The interview questions in this section aim at providing a basis for answering the second research question.

Economic performance

- What different port costs must be payed?
  - Handling costs?
  - Port charges?
  - Administration costs?
  - Other costs?
- What different costs occur connected to the transportation?
  - Vessel costs (rental cost, fuel, personnel etc.)?
  - Fees?
  - Other costs?
- How many times must the pilotage fees be paid?
- What would a pilotage exemption certificate cost? How many captains would need such a certificate for a permanent coastal shipping solution?
- What are the current costs for road and rail transportation?

Logistic performance

- What would the estimated lead time be for coastal shipping between Uddevalla and Gothenburg?
- How reliable can a coastal shipping transportation be? What affects the reliability?
- Would a coastal shipping arrangement be flexible regarding volume?
- How often do you handle container vessels? Do you have equipment to handle containers?
- What kind of goods do you transport in containers from Uddevalla to Gothenburg?
- How long do containers wait in Uddevalla before transportation?
- What would the new coastal shipping solution imply for Port of Uddevalla?
  - Simpler/more difficult handling?
  - More or less time consuming?
  - More or less administrative work?

Environmental performance

Emissions

- What levels of CO_2, NO_x, SO_x and PM does the barge Tofte emit?
- What differences are there in emission levels between rail, road and coastal shipping (CO_2, NO_x, SO_x, PM, other)?
- How does the emissions from different transport modes affect the environment globally vs. locally?
- How has the SECA affected sea transport in Sweden? Is sea transport more or less attractive than before SECA?

External costs

- Do you believe that internalizing external costs would help to decrease the environmental impact?

- Do you believe that internalizing external costs would be beneficial for coastal shipping (economically)?
- How likely do you think it is that external costs (emissions) will be internalized in the near future?

Energy consumption

- What differences are there in energy consumption between rail, road and coastal shipping?

Fuel consumption and types of fuel

- What fuel does the barge Tofte run on?
- What is Tofte's fuel consumption?
- What fuel is the best, from an environmental perspective, to use for coastal shipping in Sweden?
- Are there any trends in what fuels that are being used in short distance shipping?
- What are the price differences between low- and high SO_x level fuels?
- How does speed affect fuel consumption?
    - What speed is preferred to use on the route Uddevalla-Gothenburg?

Congestion

- Do you think that congestion is a big problem on the route Uddevalla-Gothenburg today?
- How can the use of sea transport affect congestion on land?
- Is there any risk that the sea route between Uddevalla and Gothenburg will be congested in the near future?

Design of barge transportation

The interview questions in this section aim at providing a basis for answering the third research question.

Future changes

- Do you see any future changes in prerequisites that affect the attractiveness of coastal shipping between Uddevalla and Gothenburg?
    - Changes in costs?
    - Changes in volumes/demand?
    - Changes in port infrastructure?
    - Changes in regulations?
- What rules and regulations do you think must be changed in order to make coastal shipping more attractive?

Cost of loading and unloading

- What is the best way to load and unload the vessel? Why?
    - Would it be possible to unload directly onto the larger vessel? Why/why not?
- How many moves per hour do you think is possible with the prerequisites of today?
    - How can the number of moves per hour be increased?
- How do you calculate loading costs?
    - Crane costs?
    - Can the loading charges be negotiated?
- What do you base your port charges on? Can this be negotiated?

Choice of vessel

- What vessel is best to use for shipping containers between Uddevalla and Gothenburg? Why?
    - What speed is required?
    - Personnel costs?
    - Volume capacity?
    - Fuel?
    - Fuel consumption?

Appendix B - Economic performance calculation model

This appendix shows the three different sheets that are included in the economic performance calculation model that was used to evaluate the theoretical case in this study. The sheet “Input data” must be filled in by the user, and the sheets “Calculations” and “Results” will then automatically be filled in.

Sheet: Input data

Rent or buy vessel	
Rent	Buy
Fairway due model	
2017	2018
Vessel data	
Gross tonnage	
Capacity (FEUs)	
Capacity (TEUs)	
Acquisition cost (SEK)	
Lifespan (years)	
Residual value (SEK)	
Rental charge (SEK/year)	
Insurance (SEK/year)	
Maintenance (SEK/year)	
Fairway dues 2018*	
Fees (SEK/year)	
Fuel consumption (lit/h)	
Number of crew members	
Personnel cost (SEK/h per crew member)	
Route data	
Frequency (trips/year)	
Number of FEUs	
Number of TEUs	
Goods weight (tonnes/FEU)	
Goods weight (tonnes/TEU)	
Speed (knot)	
Distance (km)	
Pilotage start fee (SEK/trip)**	
Time dependent pilotage fee (SEK/0,5h)**	
Port costs at Port A	
Port charge (SEK/call)	
Costs for loading/unloading (SEK/FEU)	
Costs for loading/unloading (SEK/TEU)	
Mooring cost (SEK/call)	
Agency cost (SEK/call)	
Port costs at Port B	
Port charge (SEK/call)	
Costs for loading/unloading (SEK/FEU)	
Costs for loading/unloading (SEK/TEU)	
Mooring cost (SEK/call)	
Agency cost (SEK/call)	

* Choose your net tonnage and environmental class. Add the numbers from column 1 and 2.

Dräktig-hetsklass	Undre gräns netto-dräktighet	1. Anlöpsavgift beroende på miljöklass(kr/anlöp)*				2. Beredskap (kr/anlöp)*
		A	B	C	D/E	
1	0	0	660	1 980	2 200	660
2	1 000	0	2 520	7 560	8 400	2 520
3	2 000	0	4 950	14 850	16 500	4 950
4	3 000	0	7 890	23 670	26 300	7 890
5	6 000	0	14 490	43 470	48 300	14 490
6	10 000	0	21 060	63 180	70 200	21 060
7	15 000	0	26 970	80 910	89 900	26 970
8	30 000	0	30 930	92 790	103 100	30 930
9	60 000	0	36 210	108 630	120 700	36 210
10	100 000	0	42 780	128 340	142 600	42 780

** Choose your net tonnage and use the numbers from the corresponding row

Dräktig-hetsklass	Undre gräns netto-dräktighet	Lotsavgift (kr)	
		3. Start-avgift **	4. Per ½-timme***
1	0	3 960	1 210
2	1 000	5 115	1 595
3	2 000	6 270	1 925
4	3 000	7 095	2 200
5	6 000	7 920	2 475
6	10 000	10 725	3 300
7	15 000	12 210	3 795
8	30 000	13 365	4 125
9	60 000	14 685	4 565
10	100 000	18 645	5 775

Sheet: Calculations

Input			
Fairway dues gross tonnage (SEK/GT un	2,75		
Fairway dues cargo weight (SEK/tonne)	2,97		
Fuel cost (SEK/lit)	4,5		
Transport time (h/trip)			

Transportation costs	**SEK per trip**	**SEK per FEU**	**SEK per TEU**
Depreciation cost			
Rental charge			
Insurance			
Maintenance			
Fees			
Fuel cost			
Personnel cost			
Pilotage			
Fairway dues			
Total transportation cost			

Port costs at Port A	**SEK per trip**	**SEK per FEU**	**SEK per TEU**
Port charge			
Cost for loading/unloading			
Mooring cost			
Agency cost			
Total costs Port A			

Port costs at Port B	**SEK per trip**	**SEK per FEU**	**SEK per TEU**
Port charge			
Cost for loading/unloading			
Mooring cost			
Agency cost			
Total costs Port B			

Total port costs			

Sheet: Results

The total cost of your sea transportation

	SEK per trip	**SEK per FEU**	**SEK per TEU**
Transport cost			
Port cost			
Total cost			

Quick change of input data

Frequency (trips/year	< >	0
Number of FEUs	< >	0
Number of TEUs	< >	0

* Fill in the cost of your corresponding road and rail transportation

Cost comparison per FEU

	Coastal shipping	**Road**	**Rail**
Transport cost			
Handling cost			
Total cost			

Appendix C - Input data for TrExTool 2.0

This appendix presents the data used for calculating the environmental performance of the coastal shipping solution and the road and rail transports between Port of Uddevalla and Port of Gothenburg. The data was used as input to the calculation tool TrExTool 2.0.

Data for the coastal shipping solution:

	Route definition					
Transport/ Warehousing	From (optional)	To (optional)	Distance Expected (km)	Distance Uncertainty (±km)	Time Expected (h)	Time Uncertainty (±h)
Transport	Uddevalla	Gothenburg	102	2	9,0	1,0

Cargo definition				Vehicle Definition			
Cargo definition	Load weight (Tonne)	Load volume (m3)	Load TEU (TEU)	Vehicle Type	Vehicle	Emission Standard	Energy Carrier
General Cargo	2 520	3 200		Ship	Container - Coastal - 5000 dwt - 571 TEU	NOx Tier 0	MGO 0.1%S

Empty Positioning		Loading		
Empty Positioning Factor Low (% of Distance)	Empty Positioning Factor High (% of Distance)	Load Factor Low (%)	Load Factor Expected (%)	Load Factor High (%)
0	0	10	80	100

Costal (% of Distance)	Inland Waterways (% of Distance)	Ocean (% of Distance)
100	0	0

Data for the road transport:

	Route definition							
Transport/ Warehousing	From (optional)	To (optional)	Distance Expected (km)	Distance Uncertainty (±km)	Time Expected (h)	Time Uncertainty (±h)	Transport during day time (Road/Train Transport (% of distance)	Transport during peak time (Road/Train Transport (% of distance)
Transport	Uddevalla	Gothenburg	87	2	1,2	0,1	100	0

Cargo definition				Vehicle Definition			
Cargo definition	Load weight (Tonne)	Load volume (m3)	Load TEU (TEU)	Vehicle Type	Vehicle	Emission Standard	Energy Carrier
General Cargo	1 500	2 895		Truck	Truck With Trailer 40-50t - Max Load 33t	Euro V	Diesel

Topography	Goods or empty?	Empty Positioning		Loading		
Gradient		Empty Positioning Factor Low (% of Distance)	Empty Positioning Factor High (% of Distance)	Load Factor Low (%)	Load Factor Expected (%)	Load Factor High (%)
Flat	Transport of goods	0	0	10	91	100

Local environment definition			
Urban > 500 000 inhabitants (% of Distance)	Urban < 500 000 inhabitants (% of Distance)	Rural (% of Distance)	Extra Rural (% of Distance)
10	5	85	0

Data for the rail transport:

	Route definition							
Transport/ Warehousing	From (optional)	To (optional)	Distance Expected (km)	Distance Uncertainty (±km)	Time Expected (h)	Time Uncertainty (±h)	Transport during day time (Road/Train Transport (% of distance)	Transport during peak time (Road/Train Transport (% of distance)
Transport	Uddevalla	Gothenburg	80	0	1,5	0,5	100	0

Cargo definition				Vehicle Definition				Topography
Cargo definition	Load weight (Tonne)	Load volume (m3)	Load TEU (TEU)	Vehicle Type	Vehicle	Emission Standard	Energy Carrier	Gradient
General Cargo	1 500	2 895		ElectricTrain	Large Train - 1500Gt		SE Mix	Flat

Empty Positioning		Loading		
Empty Positioning Factor Low **(% of Distance)**	**Empty Positioning Factor** High **(% of Distance)**	**Load Factor** Low **(%)**	**Load Factor** Expected **(%)**	**Load Factor** High **(%)**
0	0	20	100	100

Local environment definition			
Urban > 500 000 inhabitants (% of Distance)	**Urban < 500 000 inhabitants (% of Distance)**	**Rural (% of Distance)**	**Extra Rural (% of Distance)**
10	5	85	0

Appendix D - Results of environmental calculations in TrExTool 2.0

The table below presents the different emissions from the studied coastal shipping solution and the road and rail transport solutions that it is compared to. The numbers for the coastal shipping solution are adjusted from TrExTool to better represent the fuel consumption of the barge pusher (see further explanation in section 2.5.5).

	CO_2 (kg)	NO_x (kg)	SO_x (kg)	PM (kg)	Energy (MJ)
Coastal shipping	7096	198	4,5	1,2	96 190
Road	4302	19	0,01	0,17	59 153
Rail	286	0,0	0,0	0,0	26 227

The second part of the results from TrExTool are related to the external costs. The table below shows the external costs for each transport mode where the costs for sea transport are adjusted according to the fuel consumption of the barge pusher (see section 2.5.5).

	Sea	**Road**	**Rail**	
Noise	0	52	17	Euro
Congestion	0	74	0	Euro
Accidents	0	146	11	Euro
Up/down Stream	33	119	19	Euro
Nature	0	37	9	Euro
Soil and water	0	43	1	Euro
Fossil fuel	468	142	0	Euro
CO_2 fossil	1 206	366	24	Euro
CO_2 renewable	0	0	0	Euro
N_2O	19	2	0	Euro

CH_4	0	0	0	Euro
Total GHG	1 225	368	24	Euro
NO_x	1 027	50	0	Euro
CO	4	2	0	Euro
HC	10	0	0	Euro
PM	61	7	0	Euro
SO_2	18	0	0	Euro
Heat/Electricity	0	0	0	Euro
Sum External Costs	2 846	1 041	82	Euro
Sum Total	2 846	1 041	82	Euro